BIOLOGY

BOOK VI

(Experimental Edition)

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BIOLOGY

BOOK VI

(*Experimental Edition*)

A TEXT BOOK FOR SECONDARY AND HIGH SCHOOL CLASSES

Prepared by

NCERT STUDY GROUP IN BIOLOGY

NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING

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PREFACE

In Presenting Biology Books IV—VI, designed for use in the high school classes in our country, we have extended the biological concepts already enunciated in the earlier series I—III published in 1968 for use in our middle schools. In formulating the curriculum for high schools, we have been guided primarily by the basic principles that there is an urgent and pressing need to update the scientific content in the teaching of the dynamic aspects of biology.

In designing a higher level Biology Course we realize that to do full justice to it we need much more laboratory equipment than what is available now. Therefore, perforce, this curriculum had to be designed to suit our needs and at the same time to enhance the present standards.

To pass on from the classical descriptive approach in the teaching and learning of biology to an experimentally oriented course is not a very easy task. Still, one cannot avoid this transformation when biology as it is today is as much a specific and pricise science as any other. We have sought to approach the high school student through the environment, leading him on to the dynamic aspects of the functional mechanisms of organisms and culminating in a study of heredity, behaviour and the social implications of biology. We hope that this series will be the harbinger of greater changes in biology teaching at the higher levels of education.

The teachers and schools in the rural areas have been our great concern and we look forward to a meaningful and purposeful utilization of our material. From both the urban and rural areas, we expect to receive a well-guided appraisal of the present texts and guides. A questionnaire is appended to the books which we hope will be used to give us valuable feed back to enable us to revise our material.

It is needless to say that our group derived much inspiration from the B.S.C.S. and Nuffield materials.

We, in the Biology Study Group, are conscious of the immense support we have received from Professor D. S. Kothari, Chairman, University Grants Commission, and Dr. L. S. Chandrakant, Joint Educational Adviser, Ministry of Education, Government of India, on all occasions. To Professor S. V. C. Aiya, Director, NCERT, Sarva Shris Rajendra Prasad, G. S. Baderia and S. Doraiswami of the NCERT, who have always willingly given us of their time and talent in the fulfilment of our task, we offer our best thanks.

We sincerely feel that fullest advantage would be derived if the material presented here is made use of either in English or as translations into regional languages on a national scale. It is only then that our efforts would have been fully put to test.

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T. S. Sadasivan

CHAPTER I

HEREDITY

Introduction

You may have noted that brothers and sisters often resemble one another as well as their parents in certain respects. This resemblance is not due to the similarity in environments but is transmitted by the parents to their offspring during reproduction. The transmission of characters from the parents to the offspring is called *heredity*. These organisms also differ from one another in some other aspects. These differences are called variation. Heredity and variation can both be understood if we observe the constancy and variation of certain characters during succeeding generations of an organism. In this respect, some important experiments were made during the last two centuries by the German naturalist Koelreuter (1733-1806), the English vegetable botanists Knight (1799) and Goss (1824), the German botanist Gaertner (1823), and the Austrian monk Gregor Mendel (1822-1884). The contributions of the last worker were most outstanding.

Mendelism

Gregor Mendel (1822-1884) was the son of a farmer and was educated at the University of Vienna. He studied physical science and natural history. During his studentship he came under the influence of his teacher Franz Unger (1800-1870) who was professor of Plant Physiology at Vienna. The Professor did not believe in the fixity of species. He was also interested in finding the principles underlying variation. Thus, on the advice of his teacher, Mendel started his studies for understanding the problem of heredity and variation on the common pea (*Pisum sativum*). He carried out experiments in the garden of his monastery at Brunn to study the resemblances and differences amongst the various varieties of garden pea. He considered the pea to be the most suitable material for his experimental studies because,

1. the pea can be had in the form of varieties which breed true for a number of pairs of *contrasting characters* (Table 1).
2. two varieties of peas can be crossed easily so as to produce fertile hybrids, and
3. natural reproduction in pea takes place by self-pollination.

Experimental procedures

Mendel collected thirty-four *true breeding* varieties of pea from the nursery. In these varieties, he found that some characters remained constant during successive generations. He selected twenty-two varieties for his experiments and considered seven pairs of contrasting characters (Table 1).

TABLE 1

Character variation in pea plant

Character	*Nature of differentiation into pairs of contrasting characters*	
1. *Seed shape*	*Round or Smooth*	*Wrinkled*
2. *Cotyledon colour*	*Yellow*	*Green*
3. *Colour of seed coat*	*Grey*	*White*
4. *Shape of the pod*	*Inflated*	*Constricted*
5. *Colour of the pod*	*Green*	*Yellow*
6. *Position of the flower*	*Axillary*	*Terminal*
7. *Height of the plant*	*Tall* 180-210 *cm*	*Dwarf* 15-22 *cm*

Mendel felt that earlier workers had not taken into consideration the following points in their experiments :

1. When two parents were involved in sexual reproduction, studies were not carried out for a sufficient number of succeeding generations.
2. There was no attempt made to classify the offspring and count their number in each category.
3. Thus, no numerical relations were worked out amongst different categories which existed amongst the different members of the same as well as different generations.

Mendel started hybridization experiments with two varieties which were true-breeding. He called them as P_1 and P_2, i. e., parents. They differed from each other for a single pair of contrasting character. One variety produced tall plants and the other variety produced dwarf plants. He cross-pollinated the two varieties and produced hybrids between them. He called them as the hybrids of the first generation (F_1). In some of these "crosses" he used the tall plants as pollen parents and the dwarf plants as the seed parents but in other crosses he did the reverse. In these reciprocal crosses all F_1 hybrids came out to be similar. They were all tall and thus had a resemblance only with one of the parents. He then self-pollinated the F_1 offspring, collected the seeds carefully and germinated them. He found both tall and dwarf plants appearing in the next generation, called F_1 (Table 2). The progeny consisted approximately of 75% tall and 25% dwarf plants i. e., in 3 : 1 ratio.

On further self pollination, the dwarf plants bred true. Amongst the tall plants, however, only one-third bred true. The remaining two-third again segregated in the following generation in the same way as F_1 plants did. Thus, the F_2 progeny comprised pure tall, hybrid tall and pure dwarf plants in the ratio 1 : 2 : 1 respectively.

Mendel repeated these experiments keeping in consideration each one of the seven pairs of contrasting characters (Table 2). He found that in F_1 only one character out of every pair manifested itself while the other remained suppressed. He called the former as *dominant* and the latter which reappeared in F_2, as *recessive*. The two contrasting characters of a pair always segregated in F_2 in the ratio of three apparently dominant to one recessive. A cross concerned with one pair of contrasting characters is called *monohybrid cross.* Similarly crosses involving two and three pairs of contrasting characters are called dihybrid or trihybrid crosses respectively.

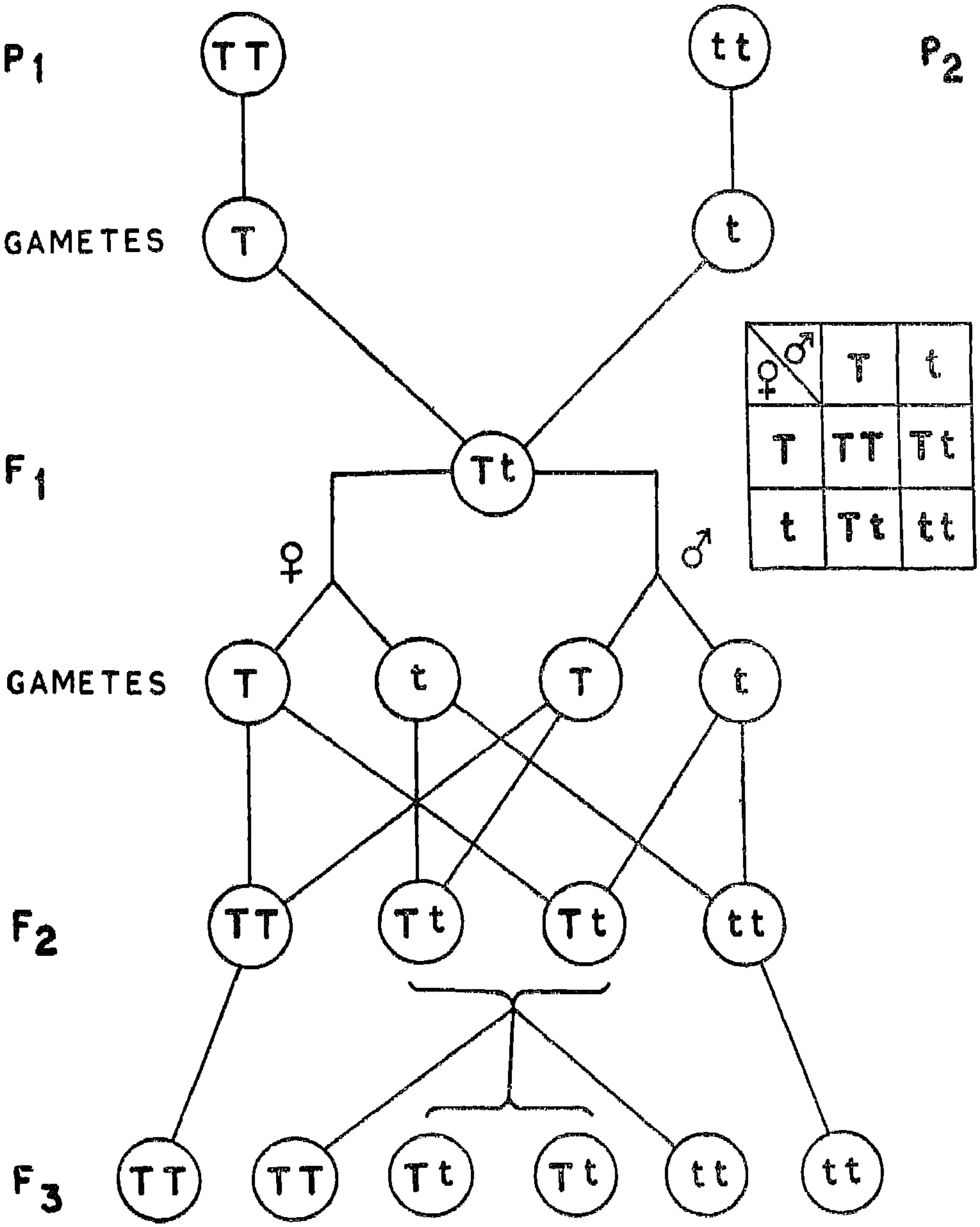
Explanation

Mendel suggested that each character is determined by something he called as a factor or a determinant. Now we call these factors as genes. The two factors which determine a pair of contrasting characters are considered to be different forms of a *gene* and are called as *alleles.* He denoted the factors with letters of the alphabet. The capital letters were used for the factors determining dominance and the small letters for recessiveness.

You would remember that in the sexually reproducing organisms, the male and the female gametes form a link between the parents and the offspring. Mendel suggested that during sexual reproduction both the parents contribute these factors through the gametes in equal proportion to the offspring. In the case of true breeding organisms, there is only one type of factors. Consequently, they produce both male and female gametes with similar factors. Thus, these gametes on fertilization produce offspring which retain constancy of a character for which the factors or the determinants have been passed from one generation to the next. This is why a pure tall pea plant produces tall offspring on self-pollination, like the pure dwarf pea plant which produces dwarf offspring on selfing.

In the cross between a pure tall and a pure dwarf, let the letters T stand for tallness and t for dwarfness. Thus, the pure tall parent produces gametes carrying only the factor T and similarly, the pure dwarf parent produces gametes which carry only the factor t (Fig. 1.1). When the two parents are cross—pollinated with one another, they correspondingly contribute factors T and t. In the F_1 offspring, although both the factors are present, only one of them which determines dominance can express itself. Thus, only factor T can express itself in the F_1 offspring and that is why they are all tall.

When gamete formation takes place in the F_1 offspring the distribution of the factors T and t to the gametes is at random. But gametes



♀ \ ♂	T	t
T	TT	Tt
t	Tt	tt

FIGURE 1.1 The progeny of three generations between tall and short characters in a monohybrid cross. T—tall; t—short. F_1, F_2, F_3—Filial generations 1, 2, 3.

can carry only one factor, either T or t. Also, the two factors while present together in F_1 offspring, remain unaffected by one another. Consequently, they are passed on to the gametes in pure form, exactly as they were during the previous generation. Their ability to determine their respective characters, i.e., tallness and dwarfness, remains unaltered. Thus the F_1 offspring produce two types of gametes in equal proportion (Fig. 1.1).

When the F_1 offspring are self-pollinated the union of the pollen grains and the eggs carrying factors T and t is also a random process.

TABLE 2

Data obtained by Mendel during hybridization experiments with pea for seven pairs of differentiating characters

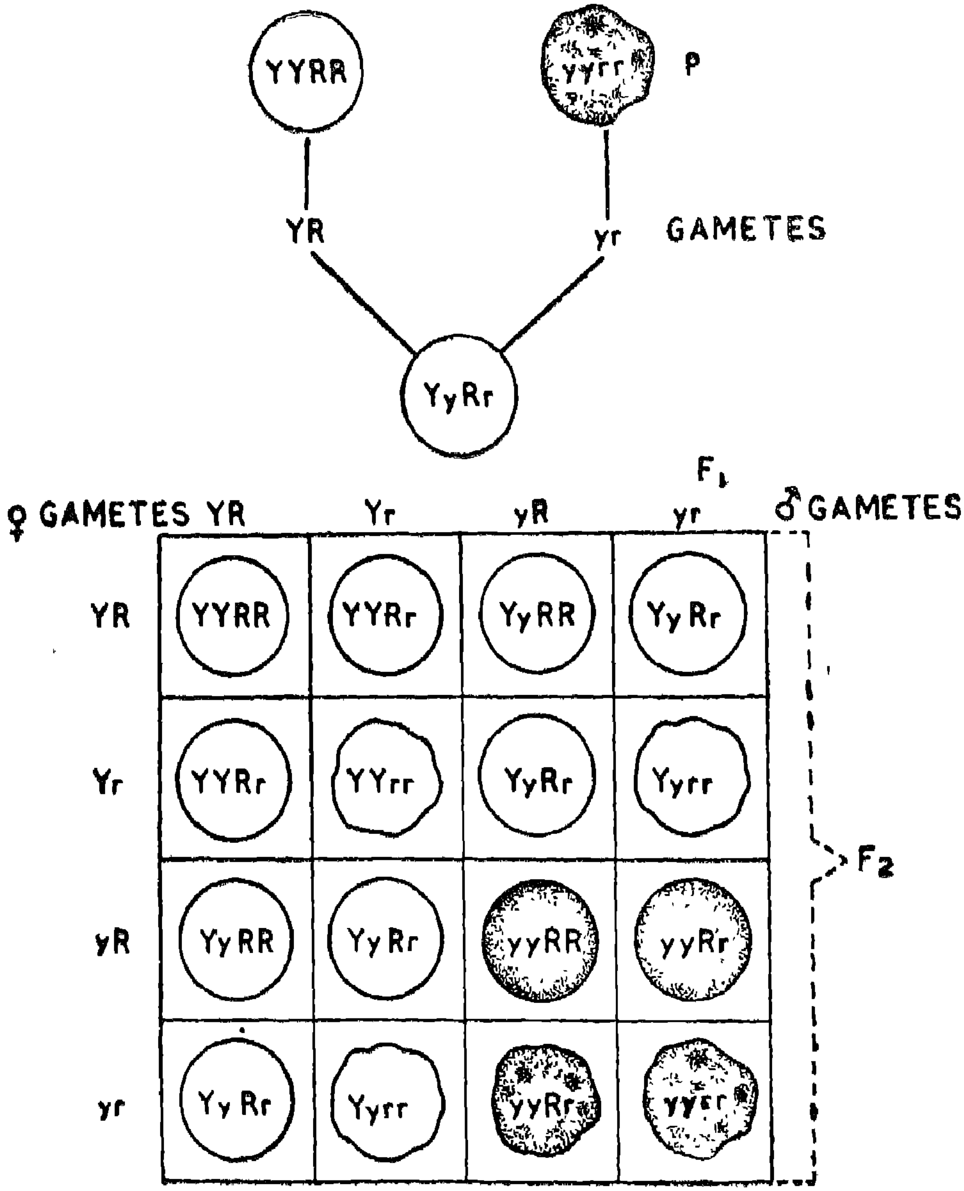
P	*F_1*	*F_2*	*Total*	*Segregation*
Seed				
Round × Wrinkled	*Round*	*Round* 5474, *Wrinkled* 1850	7324	2.96 : 1
Coloured × White	*Coloured*	*Coloured* 705, *White* 244	949	3.15 : 1
Cotyledons				
Yellow × Yellow green	*Yellow*	*Yellow* 6022, *Green* 2001	8023	3.01 : 1
Seed Pod				
Inflated × Wrinkled	*Inflated*	*Inflated* 882, *Wrinkled* 229	1111	2.95 : 1
Green × Yellow	*Green*	*Green* 428, *Yellow* 152	580	2.82 : 1
Flower				
Axillary × Terminal	*Axillary*	*Axillary* 651, *Terminal* 207	858	3.14 : 1
Plant				
Tall × Dwarf	*Tall*	*Tall* 787, *Dwarf* 277	1064	2.84 : 1

The two dissimilar gametes, i.e., with T and t have as much chance of fertilization as the two similar ones. Consequently, three types of zygotes are produced (Fig. 1.1) in F_2 generation. Amongst them, approximately 25% carry TT, 50% Tt and the remaining 25% carry tt. Since the factor t cannot express itself in the presence of factor T which is dominant and determines tallness, all plants carrying T are tall. Thus in the F_2 generation the plants which carry TT or Tt look similar and the F_2 offspring comprise 75% tall and 25% dwarf. Half of the total F_2 offspring, however, carry factors Tt and are thus hybrid tall. They breed like the F_1, i.e., they are hybrids and on further selfing produce both tall and dwarf plants in 3:1 ratio in the following generation. They are called *heterozygotes* because they arise from, as well as give rise to, dissimilar gametes with respect to the factors they carry. In contrast to this, the pure breeding tall or dwarf plants are called *homozygotes* because they always involve similar gametes.

You would remember that the tall plants in the F_2 generation are of two types. Two-third amongst them carry factors Tt and the remaining one-third carry TT. This distribution is based on the genes or the factors they carry. We can also call them as two categories of *genotypes* which look similar. In contrast to this, a distinction based on the morphology is called *phenotypic*. Thus, in the F_2 generation, there are two categories of phenotypes i.e., tall and dwarf but, three categories of genotypes, i.e., pure tall TT, hybrid tall Tt and pure dwarf tt.

Dihybrid cross

Mendel extended his experiments to two pairs of contrasting characters, for example round vs. wrinkled seed and yellow vs. green cotyledons. Thus, in a cross between pure dominant and pure recessive for both characters the F_1 offspring came out round yellow. This means that the round and yellow characters were dominant over wrinkled and green characters respectively. They produced four types of gametes with sixteen possible combinations but only four phenotypes in F_2. They were round yellow, round green, wrinkled yellow and wrinkled green in 9:3:3:1 ratio respectively (Fig. 1.2).



♀ GAMETES	YR	Yr	yR	yr
YR	YYRR	YYRr	YyRR	YyRr
Yr	YYRr	YYrr	YyRr	Yyrr
yR	YyRR	YyRr	yyRR	yyRr
yr	YyRr	Yyrr	yyRr	yyrr

FIGURE 1.2 Progeny of dihybrid cross between yellow round seeds and green wrinkled seeds in Pea.

YYRR—Yellow Round seed; yyrr—Green Wrinkled seed.

Yellow Round
YY RR
YR

Green Wrinkled
yy rr
yr

Yellow Round
YyRr

Gametes	*YR*	*Yr*	*yR*	*yr*
YR	*YYRR* *Yellow Round*	*YYRr* *Yellow Round*	*YyRR* *Yellow Round*	*YyRr* *Yellow Round*
Yr	*YYRr* *Yellow Round*	*YYrr* *Yellow Wrinkled*	*YyRr* *Yellow Round*	*Yyrr* *Yellow Wrinkled*
yR	*YyRR* *Yellow Round*	*YyRr* *Yellow Round*	*yyRR* *Green Round*	*yyRr* *Green Round*
yr	*YyRr* *Yellow Round*	*Yyrr* *Yellow Wrinkled*	*yyRr* *Green Round*	*yyrr* *Green Wrinkled*
	Yellow Round 9 :	*Yellow Wrinkled* 3 :	*Green Round* 3 :	*Green Wrinkled* 1

Thus, in a dihybrid cross each pair of contrasting characters by itself shows a segregation of three dominant to one recessive. But the assortment of the two pairs of contrasting characters which are controlled by the different pairs of genes, is independent of one another, as the shape of the seed assorts independently of the cotyledon colour.

Back Cross

As mentioned above, the homozygous talls and the heterozygous talls look similar. It is not possible to know directly which is which. To find out this Mendel devised a breeding method which is called a *back cross*. The latter consists in the crossing of F_1 hybrids with one of the parents. On crossing the F_1 hybrid with the pure recessive parent (tt), 50% of the offspring comprise homozygous dwarf plants (tt) and the remaining 50% heterozygous talls (Tt). But on crossing the F1 hybrids with the pure dominant parent i.e., tall, the progeny comprise all tall plants (50% TT; 50% Tt). The back cross between the pure recessive parent and F_1 is called a *test cross*, because we can thus test the genic constitution of hybrid by comparing the expected results with the observed.

Tall *Tt* *Dwarf* *tt*	*T*	*t*
t	*Tt* *Tall*	*tt* *Dwarf*
t	*Tt* *Tall*	*tt* *Dwarf*

The following important conclusions emerge from Mendel's experiments:

1. Every character is controlled by a factor or a determinant or a gene.
2. A gene may exist in different forms called *alleles*. Contrasting characters are controlled by different alleles of the same gene.
3. An allele is called dominant when another allele called recessive cannot express itself in its presence.
4. A dominant and a recessive allele, when both are present in the offspring, do not affect one another but only the former expresses itself. Thus when they are passed to the offspring, i.e., F_2, through the gametes, their quality to determine dominance or recessiveness remains unaltered.
5. The gametes of the F_1 can carry only one of the two alleles i.e., either T or t, and the two types are in equal proportion. The segregation of two nonallelic genes is independent of one another.
6. Combination of the gametes is purely a matter of chance.

Incomplete dominance

During the present century our knowledge about heredity has increased manifold. Now we know that there are some contrasting characters where the dominant allele is not completely effective. This is found to be the case in flower colour in *Antirrhinum majus* and *Mirabilis jalapa*. When two plants which are true breeding for red and white flowers are crossed, the F_1 offspring bear light pink flowers which is intermediate colour between that of the two parents. The phenomenon is called *incomplete dominance*. Thus, the phenotype of the F_1 is intermediate between the two parents. On further selfing the segregation in F_2 is 1 :2:1 i.e., the red which is incompletely dominant, light pink which are hibrids and white which is pure recessive respectively (Fig. 1.3.)

Multiple genes and polygenes

There are some characters which do not show 1:1 relation between a character and a factor. Instead, they have been found to be controlled by more than one gene or even the whole genotype as is the colour of our skin. Their segregation is very complicated.

Cytoplasmic hereditary particles

During the recent years, it has been found that some characters such as chlorophyll variation in some plants, are controlled by hereditary particles which occur in the cytoplasm instead of the nucleus. They do not follow the Mendelian pattern of segregation. When crosses are made involving such organisms, no statistical ratios are recovered. The offspring resemble only the female parent which contributes the cytoplasm.

Material basis of Mendelian Heredity

You have learnt that all organisms comprise cells which form the basic units of structural and functional organization. Plant and animal cells are essentially similar. During division, the nucleus resolves into discrete threadlike structure called *chromosomes*. All chromosomes of a nucleus and all parts of a chromosome, both collectively and individually, are essential for the proper growth and development of an organism. During sexual reproduction, the male and female gametes which unite to

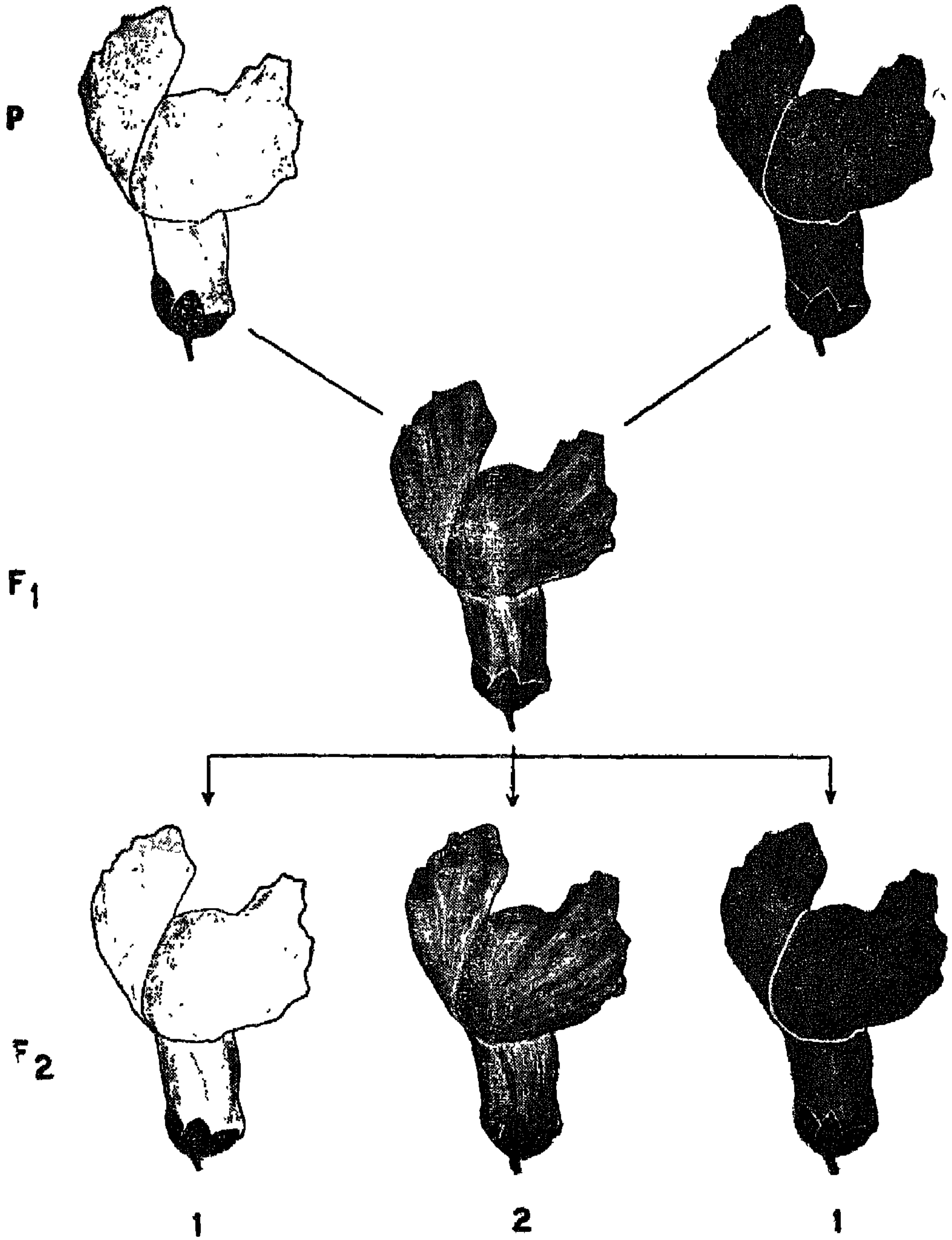


FIGURE 1.3 Dominance of flower colour in *Antirrhinum* in the F_2 generation.

form the zygote, [form the link between the two generations. But, in the case of the sperm, the nucleus forms the major part of the cell. So we may infer that it is the nucleus which forms the major link between the parents and their offspring.

During the formation of gametes in animals, cell division (meiosis) is accomplished in two stages. The result is that each sperm or the egg receives half the number of chromosomes called the *haploid number*. When fertilization takes place, this number is restored to the usual *diploid number*. In higher plants, meiosis takes place at the time of spore formation and the spores germinate to give rise to a gametophyte representing the haploid generation. The haploid chromsome number is carried through the gametes to form the zygote at the time of fertilization. The zygote then undergoes repeated mitotic divisions and develops into an adult sporophyte.

Meiosis

The two stages of meiosis are usually called as the first and the second division (Fig. 1.4). During the first stage the chromosome number is halved. The second stage is a simple mitotic division. Meiosis is effected essentially in the following stages :

1. *First Division of meiosis*

   (i) Prophase is of a longer duration than in mitosis. It starts comparatively earlier. The chromosomes appear as very long single threads in contrast to double threads at mitosis. They are diploid in number.

   (ii) The chromosomes come near each other in groups of two. This is called pairing. The two chromosomes, each of which is derived from one of the parents and undergo pairing, are called *homologous chromosomes*. The pairing is extremely specific. The two homologues lie closely apposed, side by side, end to end and point for point. The two homologues may start pairing at the ends or near the centromeres or anywhere along the chromosome length. The pairing is effected due to internal torsion of the chromosomes. Thus they are actually coiled around one another rather than just lying side by side. This can be demonstrated by placing two threads or strings side by side after giving them torsion. Each association of the two chromosomes is called a *bivalent.*

(iii) Each chromosome of a pair then undergoes a longitudinal split into two chromatids which remain close together.

(iv) Breaks occur at certain specific points of two chromatids, each belonging to one of the two homologous chromosomes. The breakage points occupy exactly the corresponding position in the homologues. Always, only one of the two sister chromatids undergoes breakage at a point.

(v) The broken ends of one chromatid then join with the broken ends of its homologue. This breakage and union between the homologous chromatids give rise to a criscross figure called *chiasma* (from the Greek letter Chi X). This event is called crossing over.

All these events take place within the nucleus. Progressive spiralization also keeps on going during the later prophase stages. Ultimately the nuclear membrane breaks and a spindle is formed. The chromosomes by now appear far smaller and condensed than what they appeared at the beginning of the prophase.

Metaphase

The bivalents arrange themselves at the equator of the spindle. The two centromeres of the two homologues repel each other and lie at an equal distance from the equator as well as from the two poles. The homologues are held together by the chiasmata.

During the anaphase, the two homologues move towards the opposite poles as the chiasma is released. The nuclear membrane appears and a nucleus is formed at each pole with half the number of chromosomes. Evidently, at the end of this division not only the chromosome number is halved, but also the genic material of every chromosome is not exactly the same as before pairing. This is because of the breakage and union of homologues chromatids during crossing over.

2. *Second division of meiosis*

It follows the usual events of mitosis, i. e.,

(i) new spindle is organized in the case of each of the two nuclei

(ii) the chromosomes which are haploid in number and each consisting of two chromatids, arrange themselves at the equator of the spindle. You will recall that one of the two chromatids in each chromosome is purely paternal or maternal whereas the other is a combination of both owing to the phenomenon of crossing over

(iii) the centromere of each chromosome replicates and the two chromatids move to opposite poles led by their respective centromeres. New nuclear membrane appears with the completion of the second division and, this completes meiosis. The result is the formation of four nuclei each with haploid chromosome number.

The chromosomes during meiosis evidently show a parallelism in their behaviour with the genes that the Mendelian principles involve, i. e., like the segregation of the two alleles which determine a pair of contrasting characters, the two homologous chromosomes also segregate randomly at the first anaphase during meiosis which follows gamete formation. Anyone of the two homologues can go to any pole. Similarly, the two chromatids also segregate randomly at the second anaphase. Like the independent assortment of two pairs of characters, the segregation of two homologues or the two sister chromatids is also independent of the others in the same nucleus. This was pointed out in the early twentieth century by Boveri (1901) and Sutton (1903). The latter was working on the chromosomes of grasshopper. He proposed that the genes are actual physical units located on the chromosomes. Also the one allele of each pair which controls the two constrasting characters, is located on each member of the homologous pair of chromosomes which form a bivalent during meiosis.

He further pointed out that (1) since the number of characters must exceed the number of chromosomes, an allele forms only a part of the chromosome. Also, (2) if the chromosomes retain their individuality, all the genes located on a chromosome must be inherited together.

Morgan (1911) and his associates working on the fruit fly, *Drosophila melanogaster* established beyond doubt that the genes are actually part of the chromosomes and are arranged in a linear order.

From the foregoing account it is evident that meiosis and fertilization alternate during every generation. During fertilization, the chromosomes are contributed to the zygote in equal proportion from gametes and a new generation is established. Thus, the halving of chromosome number which occurs during meiosis and consequently carried through the gametes, is compensated during fertilization. In this manner the two processes act in a compensatory manner to one another.

You have learnt from Mendel's experiments that for one pair of factors two types of gametes are produced and consequently genotypical three types of zygotes are produced. When two pairs of independently segregating characters are studied, an F_1 offspring produces four types of gametes and nine types of genotypes as in the F_2. Amongst these nine types, only two, i. e., double dominant and double recessive for both factors are similar to the original parents whereas the others have arisen from the various possible combinations. This process is called *recombination.* Recombination of the factors or the genes which are present on the homologous chromosomes takes place when crossing over occurs. Similarly, when the homologues and their chromatids segregate in random fashion to the opposite poles during anaphase-I and anaphase-II, recombination brought about by crossing over is within the chromosomes, whereas the one effected by segregation is between the chromosomes. The latter process is completed when random union of gametes occurs and new recombinant types are produced in the following generation manifesting heredity and variation.

Sex chromosomes

Normal human beings have fortysix chromosomes in their somatic cells. Every woman produces only one type of egg (Fig. 1.5) each having twenty-three chromosomes. Twenty-two are called *autosomes* and the twenty-third is a special one called X *chromosome*. But all men produce two types of sperm each with twenty-three chromosomes and only half of them with X. The remaining half of the sperm carry

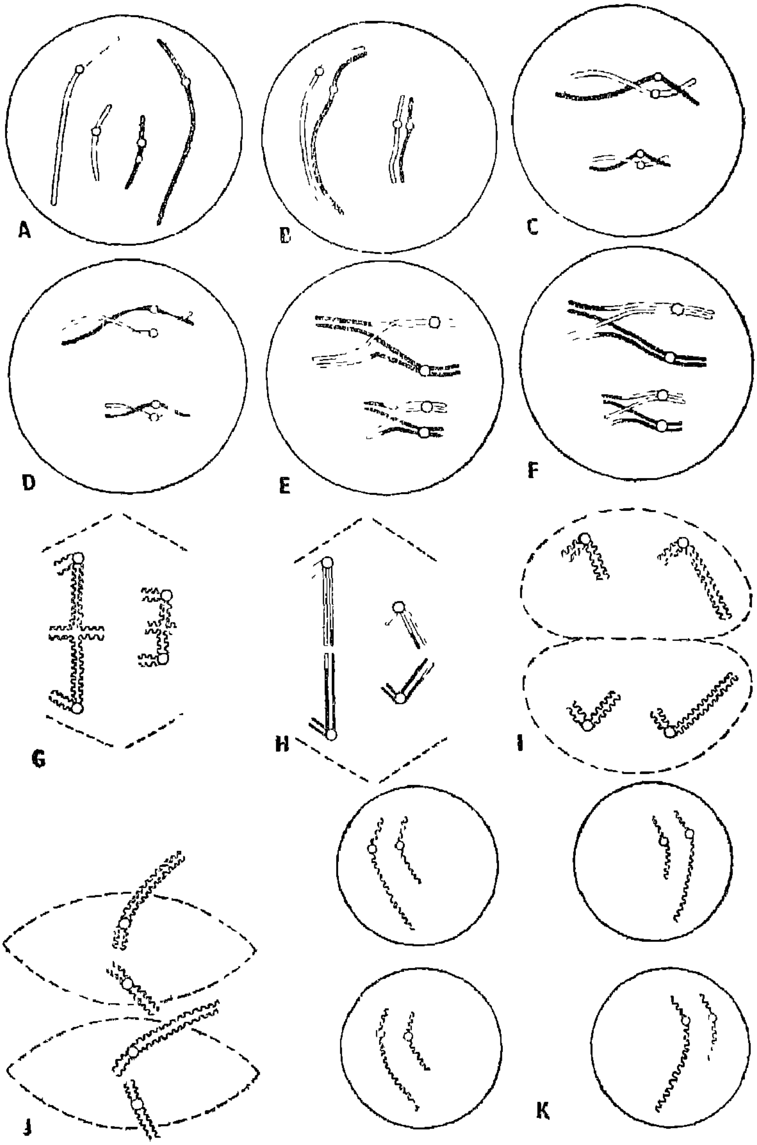


Figure 1.4 Stages in Meiosis. A-E. Prophase in meiosis (note pairing and crossing over of the chromosomes). F—Metaphase; G, H.—Early and late anaphase; I—Telophase in meiosis; J, K—Second division of meiosis.

another special chromosome called Y instead of X. When a sperm with X chromosome fertilizes an egg, a girl is produced. Similarly, when the sperm with Y chromosome participates in fertilization, a boy is born. In this manner X and Y chromosomes are important in the determination of the sex of a child. Thus, they are called *sex chromosomes*. The chromosomal contribution of males, therefore, is 22 autosomes and XY and that of females 22 autosomes and XX.

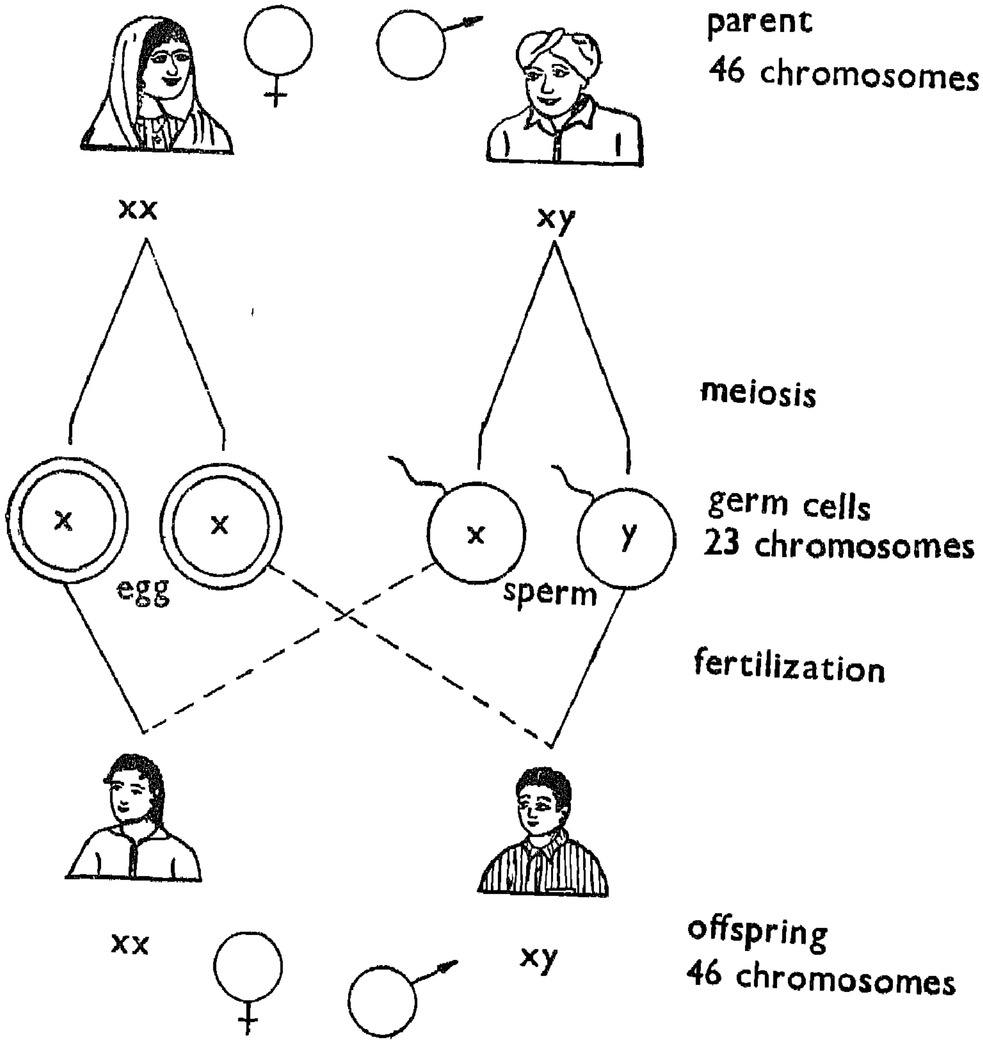


FIGURE 1.5 Sex determination in human beings.

Sex chromosomes are present in a majority of the organisms with sexual differentiation and thus we can say that :

(i) sex is determined at the time of fertilization
(ii) the sex of an individual cannot be changed unless an alteration is brought about in the sex chromosome contribution
(iii) individuals of two sexes are born approximately in equal proportion
(iv) if sex is inherited, it is obvious that the chromosomes form the basis of inheritance

Sex—linked inheritance

From the foregoing account it is obvious that there are sex chromosomes and autosomes in organisms with sexual differentiation. The characters which are controlled by the factors present on sex chromosomes, are called sex-linked characters in contrast to the autosomal characters which are controlled by the autosomes.

Chemical nature of gene

You know that chromosomes form the material basis of Mendelian heredity and that more than one gene is present in a single chromosome. You have also learnt that the chromosomes are made of proteins and nucleic acids, each of two types. The proteins are basic as well as acidic. The nucleic acids contain ribose and deoxyribose sugars and are known as RNA and DNA respectively. To know the exact chemical nature of the gene i. e., whether proteins or the nucleic acids, let us recall some of the experiments.

Griffith (1928), a British doctor, was working on a bacterium called *Pneumococcus* which is responsible for causing pneumonia. This bacterium has a disease causing strain which is characterised by the presence of a capsular coat around the cell wall (Fig. 1.6). This capsulated form proves fatal to the mice when injected. There is another non-capsulated form which is harmless (non-virulent). Griffith killed the bacteria of the virulent form by heating and injected them into the mice. He found that the heat killed bacteria were harmless. He then injected the dead virulent bacteria along with the living non-capsulated non-virulent form, He found that injecting the mixture of the two forms proved fatal. However, on examination, the isolate was found to consist of the capsulated cells. Evidently, the ability to synthesize a capsule had been transferred from the dead bacteria to the living ones which were injected together. These experiments could be repeated in the body of the animal but not in the test tube.

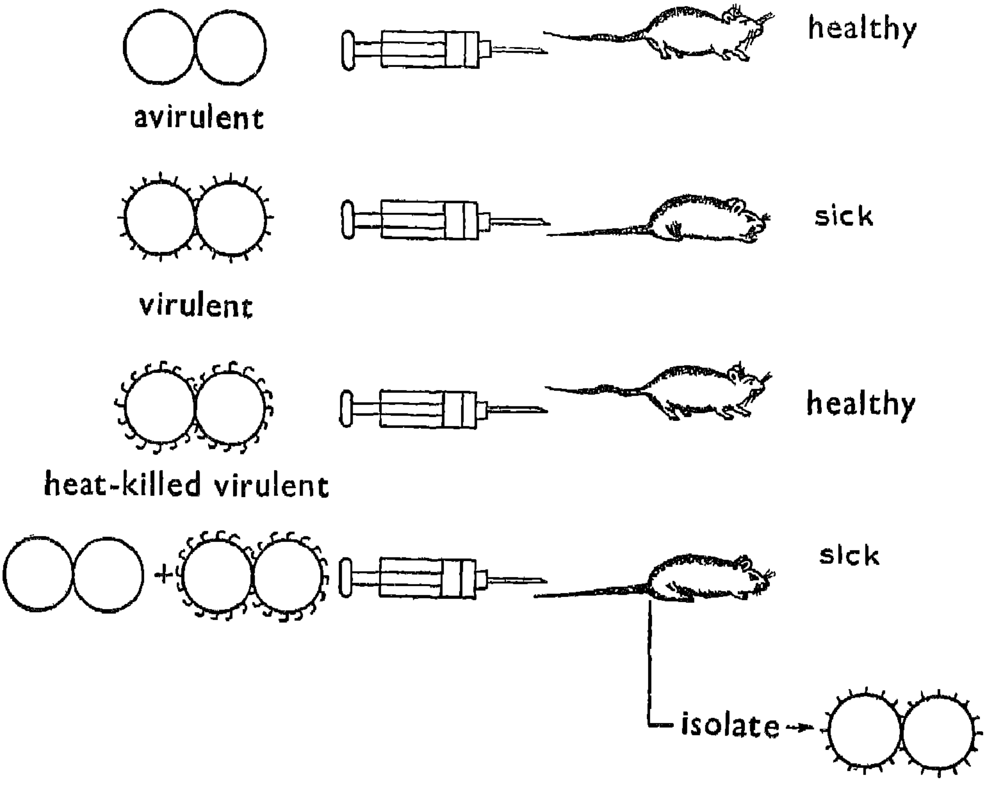


FIGURE 1.6 Experiment showing the inoculation of capsulated and non-capsulated bacterial cells in mice.

During the same years, Dawson and Avery were also working on the same problem at the Rockfeller Institute of Medical Research, New York. They confirmed the results of Griffith. Later on Dawson and his collaborators, however, succeeded in repeating these experiments in a test tube. In 1933 Alloway discovered that the crude extract of the capsulated bacteria could change the non-capsulated form into the capsulated one.

In 1944, Avery, Macleod and McCarty isolated the chemical substance causing heritable change in the bacterium in a purified form. It was found to be extremely rich in deoxyribose nucleic acid. Thus, a very convincing suggestion emerged that the chemical substance which causes change in the bacteria is DNA. This was later confirmed by Avery and his collaborators by further experimentation.

Further confirmation to this hypothesis came from the work on another bacterium, *Echerichia coli*, which inhabits human intestine. This bacterium can carry viral infection. It can be killed in about twenty seconds. The virus particles are called phage T2. During infection the synthesis of bacterial proteins and nucleic acids ceases and the phage takes over the synthetic activity within the cell. Thus, new phage particles are produced instead of the bacterial molecules. These phage particles comprise a protein coat and a DNA core. They thus exhibit genetic continuity. Later on Hershey and Chase (1952) confirmed by using radioisotopes of phosphorus and sulphur that DNA of the phage particles shows continuity over the generations and not the protein.

Structure of DNA

Deoxyribose nucleic acid is composed of three components. They are pentose sugar, phosphates and the nitrogenous compounds called *bases*. The pentose sugar has four of the five carbon atoms along with an oxygen atom arranged in a ring (Fig. 1.7A). The fifth carbon atom is attached to a side chain. The sugars combine with the bases to form nucleosides. When a phosphate group is attached to a nucleoside, it is called *nucleotide* (Fig. 1.9). The DNA molecule is a polynucleotide double helical chain. The phosphates and the sugar

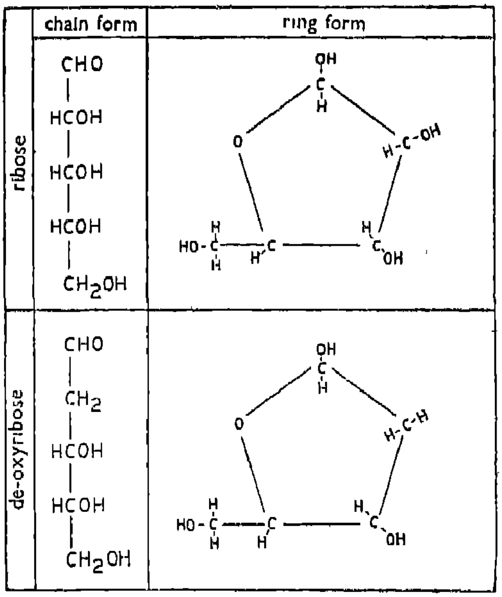


FIGURE 1.7A The structure of ribose and deoxyribose sugars in RNA and DNA.

form the backbone of the polynucleotide chain in such a manner that the two alternate with one another. The two strands of DNA molecule form a double helix looking like a spiral stair case (Fig. 1.8). The phosphates and sugar form the backbone and the steps are formed by the bases. The bases of the two strands are held together by weak hydrogen bonds.

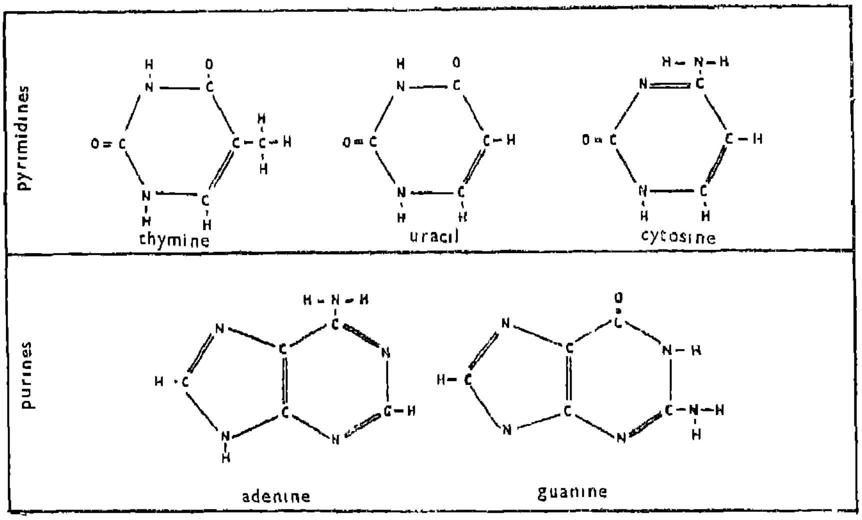


FIGURE 1.7B The structure of the DNA bases, Purines and Pyrimidines.

The arrangement of the bases along the double stranded DNA molecule is very important. There are two types of bases (Fig. 1.7B). They are purines, large molecules and pyrimidines which are small molecules. Adenine and guanine comprise purines and, thymine and cytosine comprise pyrimidines. Purines and pyrimidines are present in equal proportion in a DNA molecule. Also, the proportion of adenine is equal to that of thymine and that of cytosine equal to guanine.

The two strands of DNA are complementary to one another, i. e., adenine of one strand always pairs with thymine of the other. Similarly guanine pairs with cytosine. This complementary pairing accounts for their equal ratios in the molecule. When a new DNA is synthesized, the two strands of the molecule fall apart and new complementary nucleotides attach themselves to each strand to make them double stranded. With this process genetic continuity is maintained.

Mutations

A heritable change in an organism is called *mutation.* De Vries introduced the concept of mutation into the science of Genetics. He found that amongst the cultures of *Oenothera lamarckiana* (Evening Primrose) some new types arose spontaneously and then bred true. He suggested that evolution took place by leaps or by the process of mutation.

Now, we know the organization of the genetic material. Thus, we can define that any change in the organization of genetic material is called mutation. When mutation occurs in nature, we call it as spontaneous. Mutations can also be induced by exposing the organism to different types of irradiations or chemicals. Muller was the first to induce mutation with the help of X-ray irradiations for which he was awarded the Nobel Prize in 1946.

When mutations involve the number or structure of chromosomes, they can be observed and detected under the light

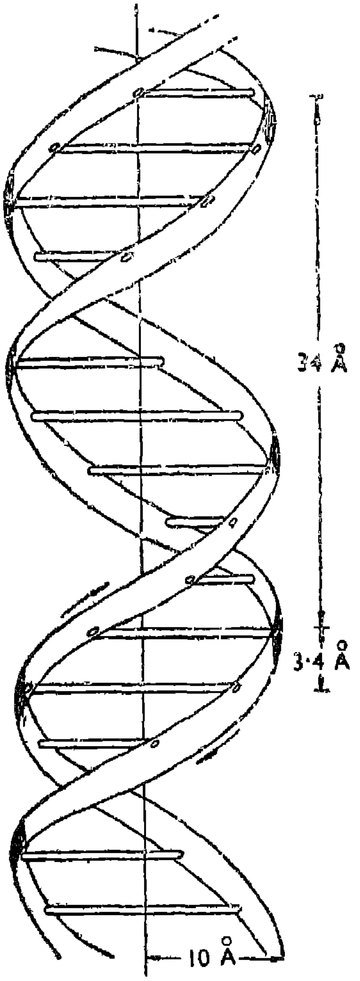


FIGURE 1.8 The helix of DNA molecule expressed in the form of a spiral staircase, length and breadth indicated in angstroms (Å).

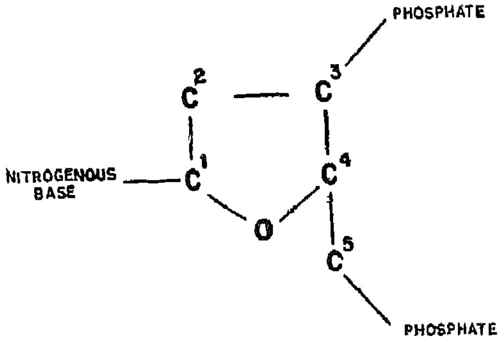


FIGURE 1.9 The structure of nucleotide in DNA.

microscope. The phenomenon also includes multiplication of the chromosome number or polyploidy. Usually we call these as *macro—mutations*. In contrast to this, the micro or point mutations cannot be detected under the microscope. They occur at the level of genes. They can be inferred only by the phenotypic expression. These are very important and form the fundamental basis of Mendelian genetics. So, mutations form the prime source of variation, and the raw material for natural selection. In the case of cultivated plants, the same principle holds good and mutants are used as raw material for evolving new varieties.

CHAPTER II

ORGANIC EVOLUTION

Introduction

The living world is immensely diverse. (Fig. 2.1) gives you a bird's eye view of the diversity in the living world. When studying classification you learnt that within this diversity there exist certain similarities. But even in closely similar groups of individuals, no two individuals are exactly alike (excepting identical twins). You can realize this fact from the following examples.

If you observe a herd of cows grazing in a field you can pick out a coloured cow from the white ones. But you may find it difficult to recognize the individuals amongst the white cows whereas the cowboy can do it. He knows the small differences in characters among them.

This shows that certain basic similarities exist between the two individuals of the same kind, but they are not exactly alike. You know that those populations of closely similar individuals which in nature breed among themselves are called *species*. You are also aware that there are innumerable and diverse species living on earth. How did these species originate ?

In your earlier class, you have studied that life originated from inorganic materials. From the study of fossils it is noticed that animals and plants have changed. This march of life through time is the subject matter of *Organic Evolution*. Today we have plenty of evidences to establish the concept and mechanism of evolution. The most prevailing idea for a long time was that animals and plants of today were in the same state as " on the first day of creation ". This was the idea of *Special Creation*, which advocated that species are *immutable*. How was the idea of immutability replaced by the concept of organic evolution ? It may be mentioned here that the idea of organic evolution was almost as old as the concept of special creation. But it gained prominence only through the work of the great British naturalist Charles Darwin, whose epoch making book *The Origin of Species* revolutionised human thought.

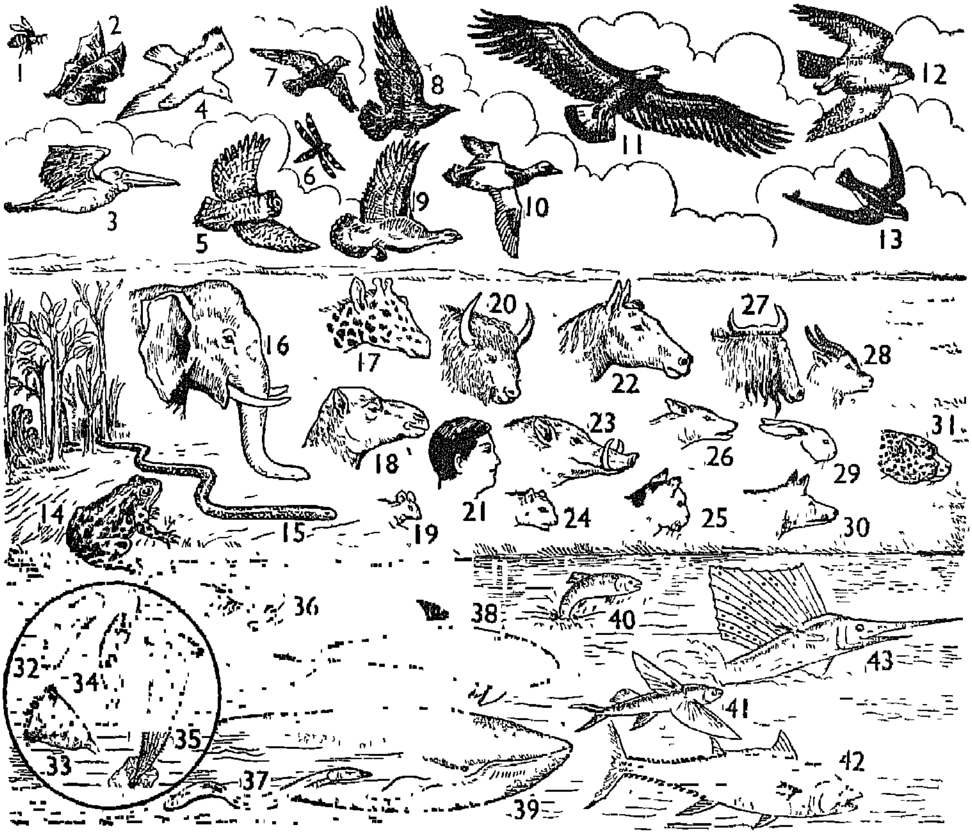


FIGURE 2.1 A small part of the great diversity that exists in the living world
1. Bee 2. Bat 3 Brown Pelican 4. Herring Gull 5. Great horned Owl 6. Dragon Fly 7. Sterling 8. Crow 9. Wild Turkey 10. Cavasback 11. Golden Eagle 12. Peregrine Falcon 13. Indian Swift 14. Frog 15. Black Mamba Snake 16. Indian Elephant 17 Giraffe 18. Camel 19. Mouse 20. Bison 21. Man 22. Horse 23. Hog 24. Weasel 25. Cat 26. Dog 27. Gnu 28. Gazelle 29. Hare 30. Fox 31. Cheetah 32-35. Various protozoa 36. Prawn 37. Eel 38. Dolphin 39. Whale 40. Trout 41. Flying fish 42. Tuna 43. Sailfish.

Examples to observe that change is universal and an operating principle in evolution

A. Change as seen in domesticated dog

Fig. 2.2 shows different varieties of dog. It is known that dog originated from wolves, jackals or coyotes. Long ago primitive man tamed these animals. These tamed forms were crossed with their wild relatives and with fellow-tamed forms. In this way distinct breeds of domesticated dogs were produced. The dogs of the eskimos resemble the polar wolves ; Indian dogs are more like the local wolves ; African dogs resemble the jackals and American dogs resemble the coyotes. Gradually many varieties of dogs were produced through *selective breeding*. All the varieties were produced by selection because they were favoured either for their beauty or utility.

B. Goldfishes in an aquarium

Look at Fig. 2.3 which shows different varieties of gold fishes. All of them were derived from the wild Chinese carp. In these cases too, domestication and conservation gave even the grotesque and ill-adapted forms an opportunity to survive. Thus marked changes from the ancestral types are distinctly visible in them.

C. Coming of a new marsh grass

Townsend's grass (*Spartina townsendi*) is an example of a marsh grass which emerged in nature almost before human eyes. In the early nineteenth century some seeds of American marsh grass (*Spartina alterniflora*) accidentally got transported to the southern coasts of England where they crossed with European marsh grass and resulted in a new hybrid called *Townsend's grass*. In the animal world such crossing usually produces sterile offspring but in plants the offsprings are sometimes fertile. The fertile Townsend's grass soon grew more vigorously than its parents and within one hundred years it became the predominating type of marsh grass in this region.

From the above examples, let us extract the essence of the cardinal principles of organic evolution. The prime feature of organic evolution

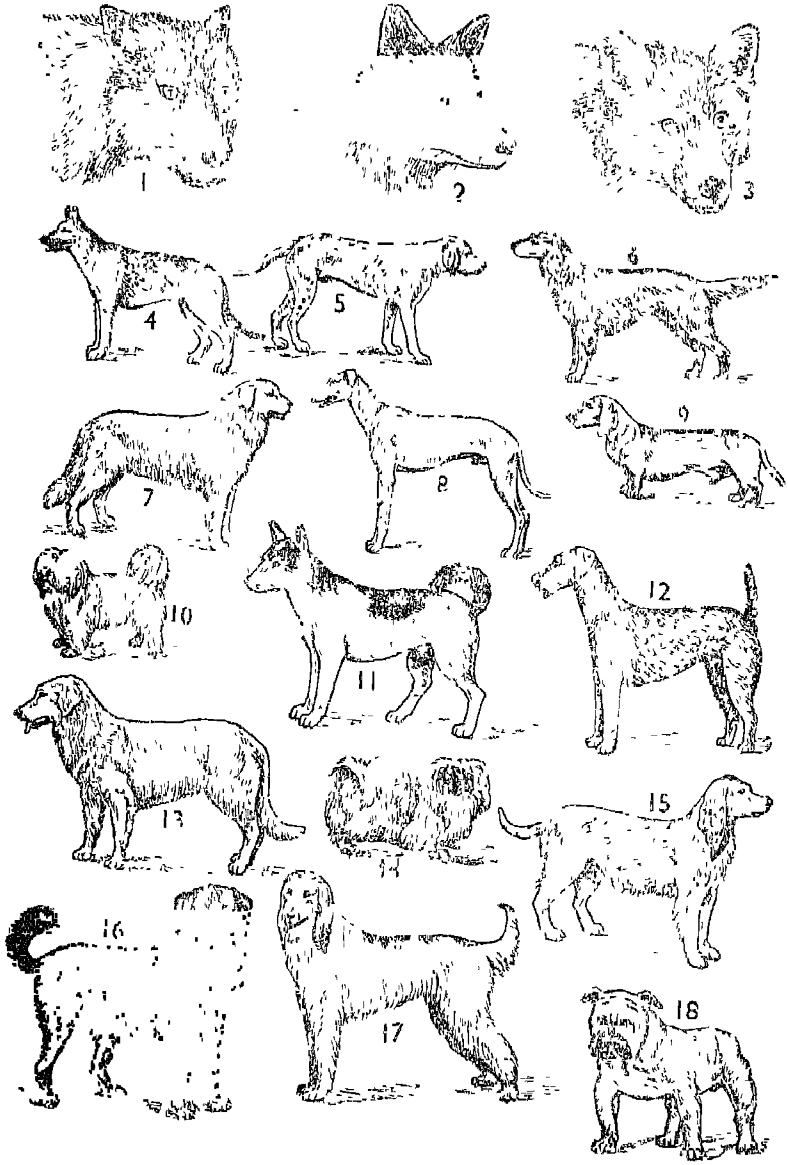


FIGURE 2.2 Various types of domesticated dogs and their three ancestors—(1) Wolf (2) Coyote (3) Fox (4) German shepherd dog (5) Barque (6) Garden Setter (7) Great Pyreness (8) Indian Greyhound (9) Dachshund (10) Lhasa apso Terrier (11) Indian Dog (12) Airedale Terrier (13) Russian Tracker (14) Pekingese (15) Italian Spaniel (16) Tibetian Mastiff (17) Afghan Hound (18) Bull Dog.

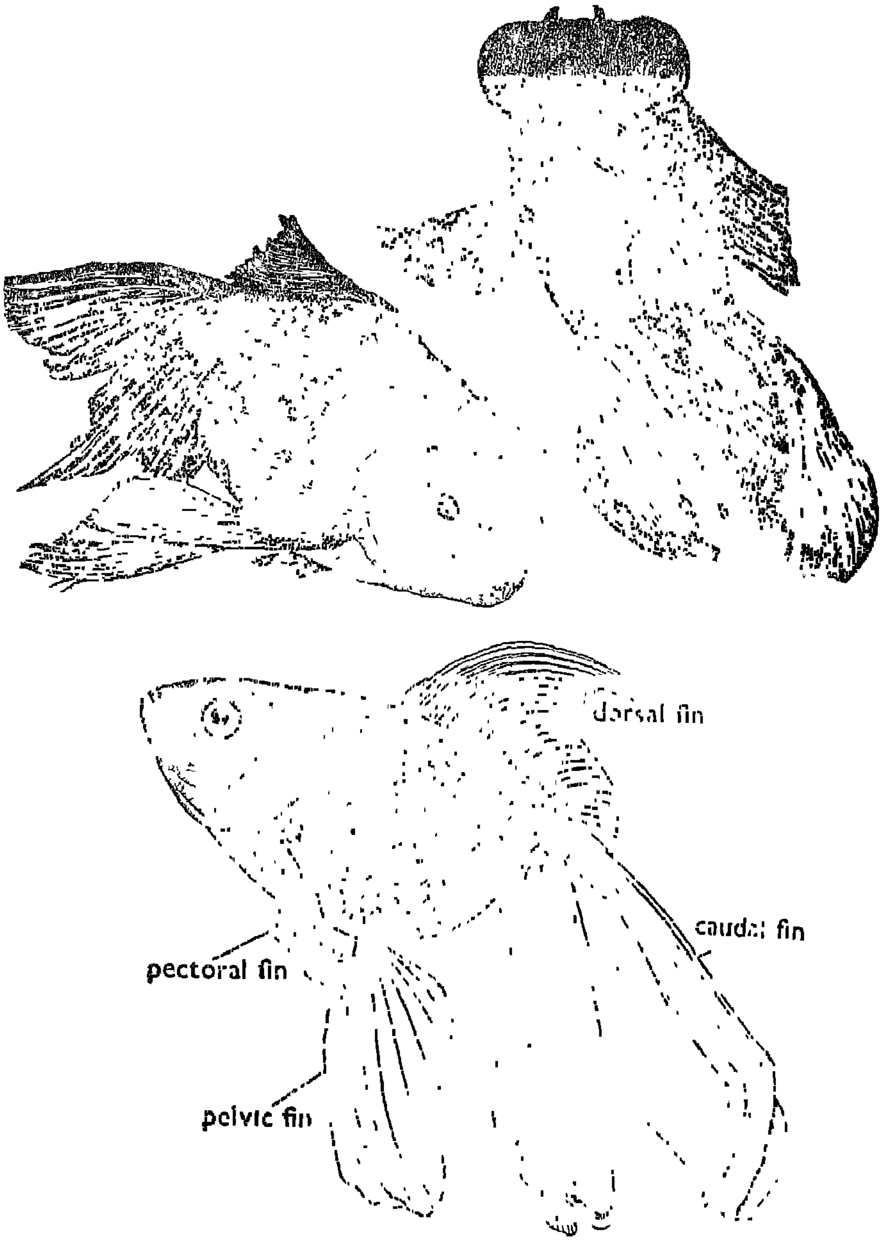


FIGURE 2.3 The Goldfishes (*Carassius auratus*). These are a few of the many varieties of goldfishes which are seen in aquaria. All the varieties of today originated from Chinese carps and it took over a thousand years of artificial selection to get these colourful forms.

is that living forms change in some way or other. Such changes take place very slowly and gradually in nature. Concurrently, a selective mechanism operates, which permits some of the changed forms to perpetuate themselves while the changed traits are transmitted through generations.

You may now ask that if such an answer is so readily available why did it take such a long time to establish the concept of organic evolution ? Today, we know more of cytology, genetics, embryology, and physiology than did the biologists of Darwin's time. This explains their inability to realize the truth. Let us now examine how Charles Darwin looked at the problem of organic evolution and how he put forward a definite concept.

Charles Darwin—his life and works

Charles Robert Darwin (Fig. 2.4) was born in 1809 in an English family to which also belonged several leading intellectuals of the country. The family wanted Charles Darwin to be a physician, but he preferred to be a student of natural history. With little formal training, he joined the carrier H. M. S. *Beagle* as a naturalist. The ship was sailing for a circumglobal scientific expedition. When Darwin left the coast of England he was twenty two years old and had the prevailing view in mind that species do not change.

The H. M. S. *Beagle* touched different coasts of South America, reached the islands of Galapogos and after a five-year voyage was back to England. Darwin, now 27 years old, came back home with a huge collection of animals, plants, rocks and fossils (Fig. 2.5). His notebooks were full of observational data. He noted that the ostrich-like

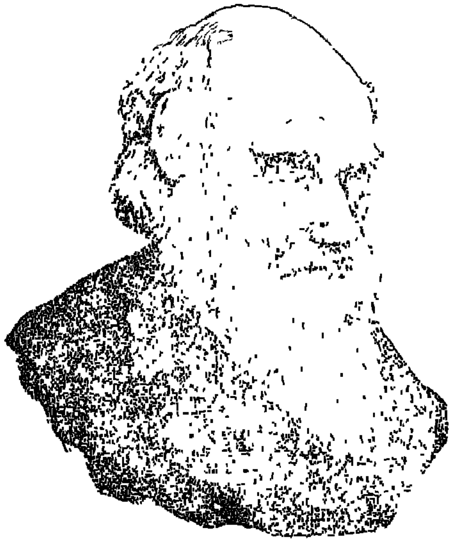


FIGURE 2.4 Charles Robert Darwin (1809-1882).

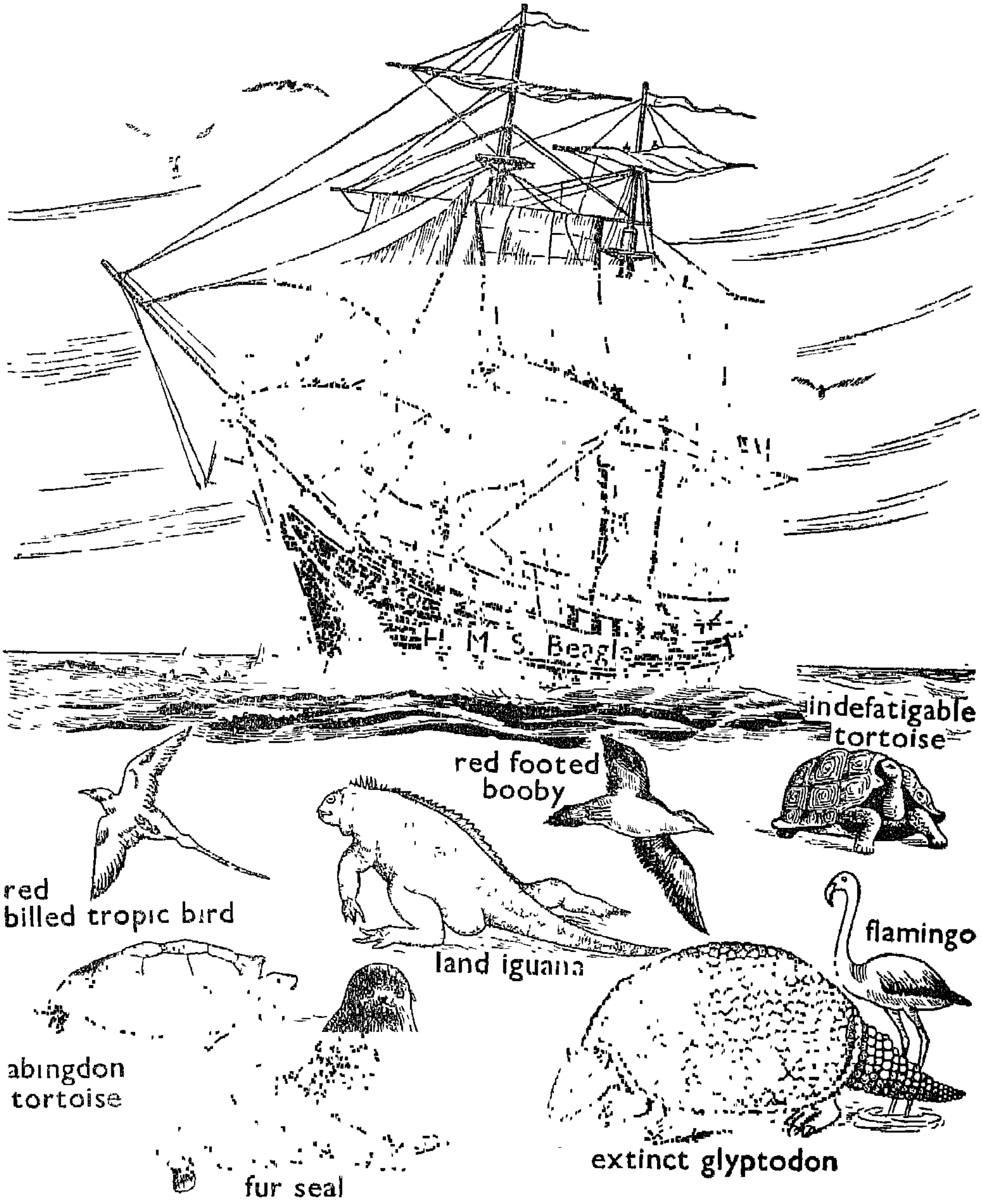


FIGURE 2.5 The ship *H.M.S. Beagle* and some specimens of the Galapagos islands which attracted Darwin.

bird *Rhea*, varies in appearance in different places of South America. A fossil resembled the present day Armadillo but was of larger size. He observed that in the islands of Galapagos, the plants and animals were different from those of the mainland though the environments did not differ much. Of special interest was a kind of bird called finches. The island finches differed markedly from the mainland forms. The finch populations of different islands also varied among themselves. There were marked differences in their food habits. Some of them were seed eaters, some fruit eaters, others were insectivorous while still others could use cactus needles to bring out the insects from under the bark.

These are a few of the many important observations which Darwin made. Being an ardent believer of the Church, Darwin was hesitant to give much publicity to his newly emerging view that closely resembling variants might have arisen from a common ancestor. He asked himself whether God had created every type of form for a particular place. Darwin published notes about his collections of the Galapagos which earned him much fame. But he never published his thoughts on variations in the living world. Like a true scientist, he wanted to collect further evidences in this regard before drawing a definite conclusion. These evidences, collected during the next twenty years, came from various sources namely, from fossils, comparative anatomy, embryology and geography.

Fossil evidences for evolution

1. Look at the geological time scale (Fig. 2.6). It gives you an idea about the different layers of the earth in relation to time. The different layers of earth become exposed to our eyes in certain places. This is due to various geological upheavals like cracking and erosion. The good examples are the Siwalik ranges in our country (in the Northern Panjab) and the Grand Canyon in the United States (Fig. 2.7).

2. Note that the earth's crust is distinguishable into five major strata representing five major time intervals, each called an *era*. Each era is subdivided into *periods*, and each period into several *epochs*.

3. From the age column you will find that the lowermost layers are the oldest and the uppermost layers are comparatively recent. Do you know how the age of different layers is determined ? The determination

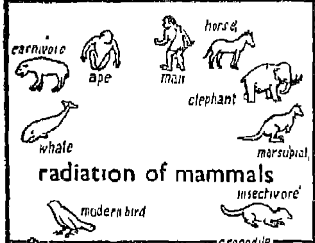
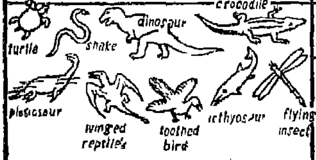
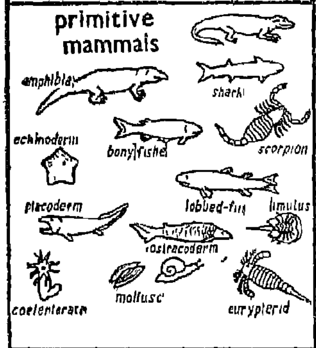
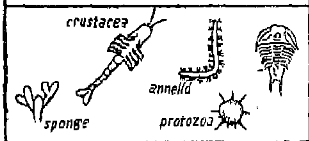
dominant animal fossils	time of duration in million years	epochs	periods	era
 carnivore ape man horse elephant whale marsupial insectivore modern bird radiation of mammals	025	recent	quaternary	cenozoic
	1	pleistocene		
	11	pliocene	tertiary	
	16	miocene		
	11	oligocene		
	19	eocene		
	17	paleocene		
 crocodile turtle snake dinosaur plesiosaur winged reptiles toothed bird icthyosaur flying insect	75		cretaceous	mesozoic
	55		jurassic	
	35		triassic	
primitive mammals  amphibia shark echinoderm bony fishes scorpion placoderm lobbed-fin limulus ostracoderm coelenterate mollusc eurypterid	45		permian	paleozoic
	90		carboniferous	
	67		devonian	
	45		silurian	
	113		ordovician	
	90		cambrian	
	375		precambrian	protero-zoic
	450			archeozoic

FIGURE 2.6 Geological time table to show some details about the different layers of the earth in relation to time.

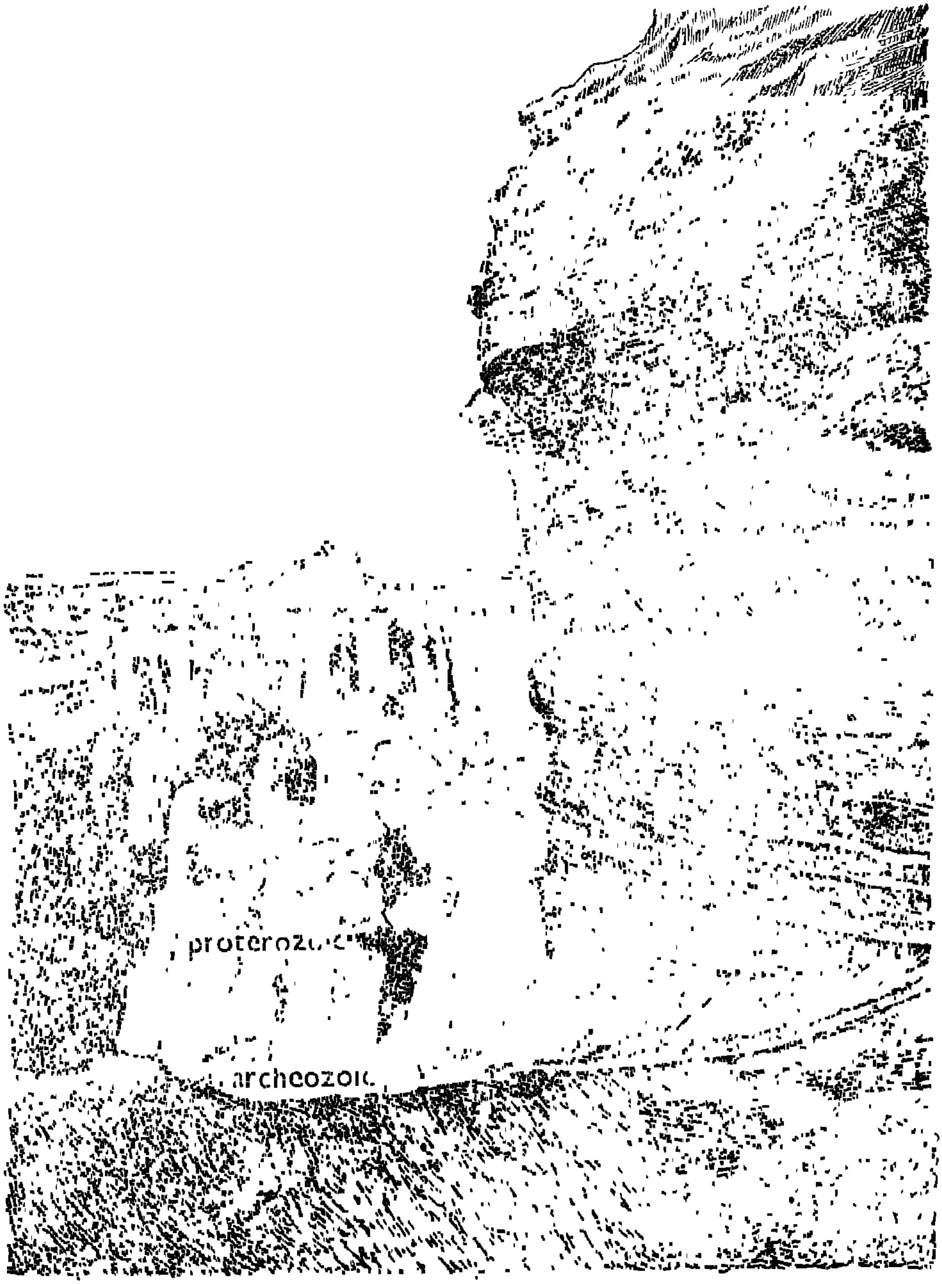


FIGURE 2.7 A view of the Grand Canyon rocks of the U.S.A., where lower layers of the earth are exposed.

of age can be correctly done only after it is known that a given quantity of the radioactive substance uranium turns into a given quantity of lead within a specified time span. The geologists have worked out the relationship of uranium and lead concentrations in each layer and have estimated its age by determining the time required for that amount of turn over.

4. Look at the column (Fig. 2.6) showing the types of fossils which were obtained from each stratum. Note that fossils are more preponderant in the upper layers than in the lower ones. These fossils do not resemble the present day forms and the fossils obtained from the lower strata are simpler than those from the upper strata. If the species are immutable, why were the present day forms absent in those long bygone days ? There lies almost a trend of succession from simple to complex body forms. For example, annelids came earlier to chordates, amphibians appeared before reptiles. There are fossils of transitional forms in between the large groups ; for instance, *Archaeopteryx*, between the reptiles and birds. It possesses such reptilian characters like the presence of teeth and clawed digits in the forelimb and diagnostic avian feature like wings with feathers.

It is evident that in course of time the layers of earth have changed. The oldest layers are at the bottom and the more recent layers are towards the surface. The fossils obtained from different layers represent the inhabitants of a particular time. They exhibit a trend of change towards more complexity. The fossils of intermediate forms are show-pieces of such changes. From Lyell's book, "Principles of Geology", Darwin learnt about these geologic changes, and while visiting South America, he noted the changed patterns of rocks. On his return, Drawin dug up the available knowledge of geology and studied the fossils to know the extent of such changes.

Evidences from comparative anatomy and physiology in living forms

A. 1. Examine the heart and brain of fish, toad, lizard and guineapig (Fig. 2.8).

2. Note that in the case of both the organs, in all these animals, there exists a common structural plan. But you find that both the organs have become more and more complex as you move higher up from fish

to mammal. After examining the structures in the dissected specimens and consulting the diagram, fill up the following table with short descriptions of the organs:

Name of the organ	*Fish*	*Toad*	*Lizard*	*Guineapig*
Heart				
Brain				

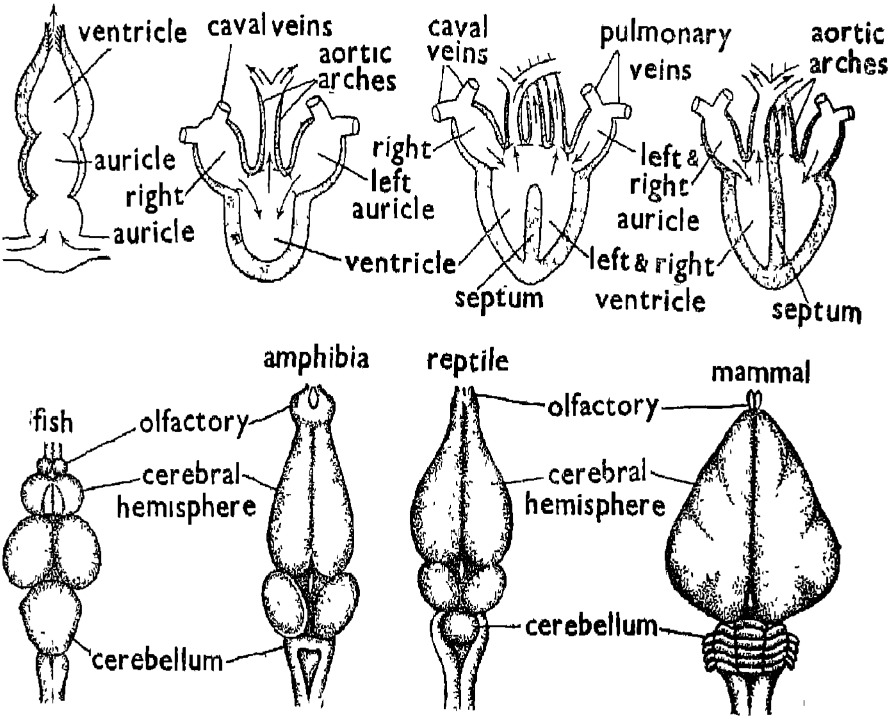


FIGURE 2.8 The structure of heart and brain in some vertebrates. Heart is shown in diagrammatic sectional view to illustrate the internal structures and the brain is drawn from its dorsal side.

B. 1. Look at Fig. 2.9. Note that these animals differ in their habits and habitats. Though they use their fore limbs in different ways, there exists a similarity in the basic structural plan, i. e., same skeletal elements are present in all of them. When these animals develop, their fore limbs are formed in the same area and follow the same pattern of development. Structures having similar origin (functionally they may not be similar) are called *homologous* organs. Remember, that organs in different animals which have only functional similarity but are of different origin are known as *analogous* organs. For instance, the wings of the cockroach and that of a bird (both are used to fly) are analogous organs.

2. What is the significance of these homologous structures ? The only answer is that the forms having homologous structures must have originated from a common ancestor and this particular structure has changed in each type according to the specific functions.

3. Do you remember, that while studying classification, the organisms were grouped on the basis of their homologous structures. For example, structurally, cat is more like tiger than dog. So the former two belong to the cat family. Again, all the three resemble each other more closely than they resemble man. So they are grouped within a common order Carnivora which is different from that of man. The biological classification is based on actual kinship of organisms, an essential evidence towards the idea of evolution.

C. 1. Fig. 2.10 illustrates some homologous structures which have lost their functions. The four vertebrae at the posterior most region of vertebral column in man are fused to form a coccyx. They are homologous to the bones which constitute the tail in other mammals. In rare cases human babies are reported to have short tails.

Can you move your pinna—the external ear ? Probably not, but many mammals like monkey and cow can do it. In spite of our inability, we still possess these muscles which other mammals use to move their pinna. The third eyelid or the nictitating membrane hangs as a transparent movable curtain in the eyes of various animals like toad and the lizard. In man, this structure has lost its function and remains at the corner of the eye. Similarly, the appendix, which is well developed in herbivorous mammals, is a vestigeal organ in our alimentary canal. If

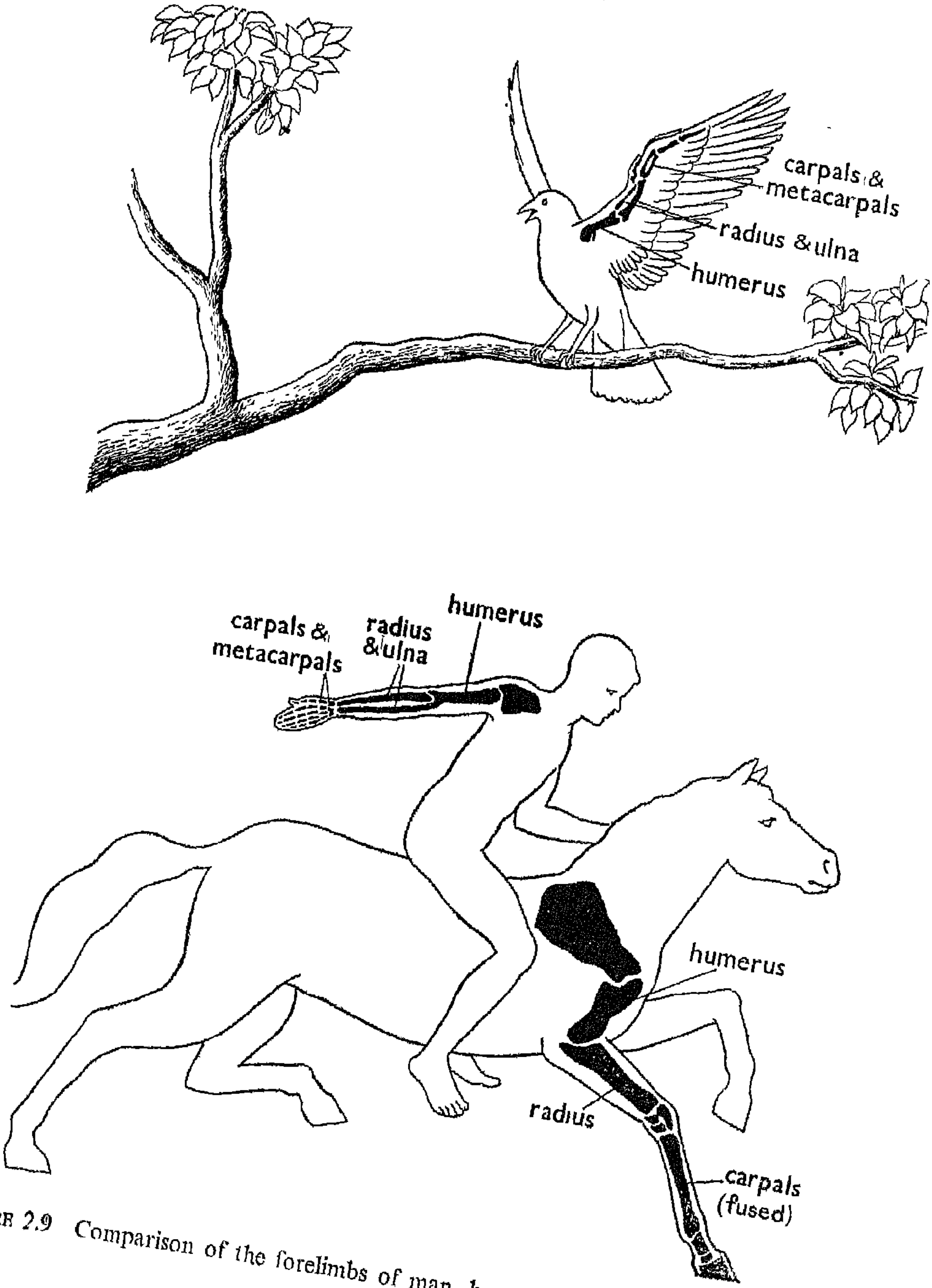


FIGURE 2.9 Comparison of the forelimbs of man, horse and a bird.

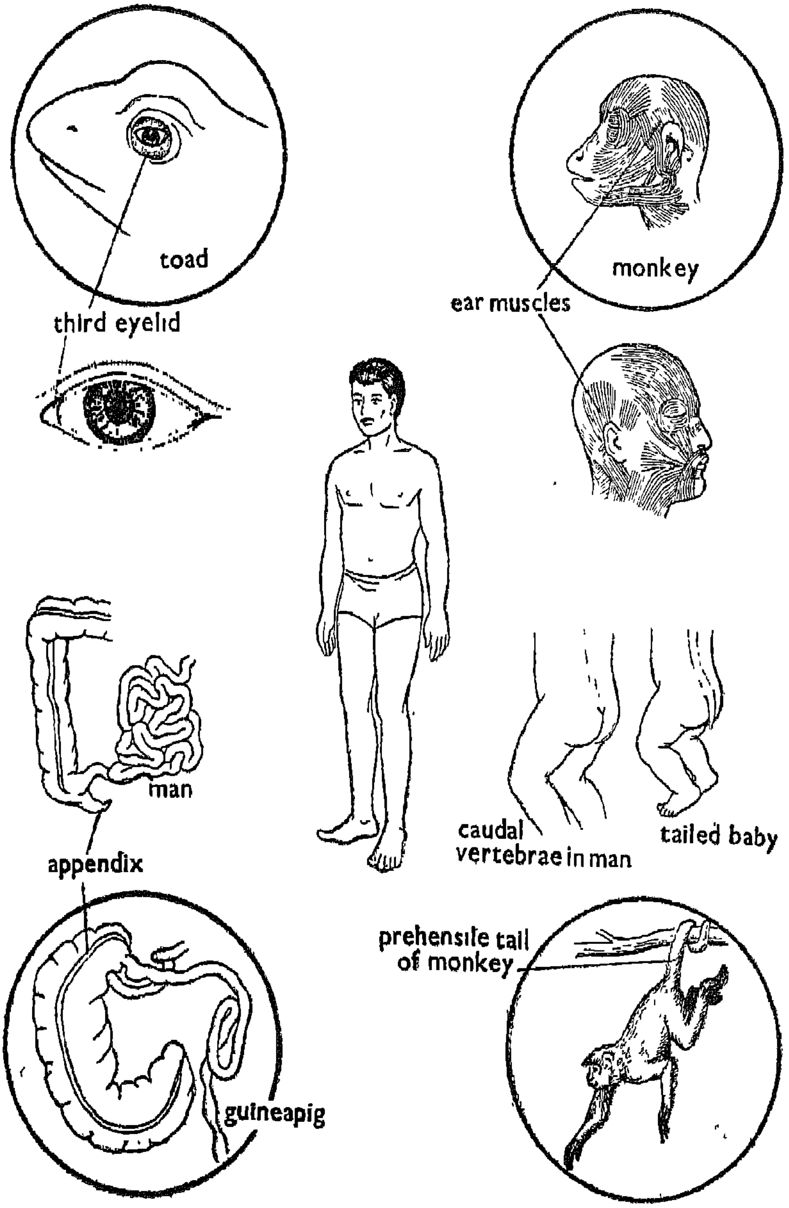


FIGURE 2.10 Some vestigial organs of man. Within the boxes are shown the corresponding structures in other animals where they are functional.

every organism was the result of special creation, why are some forms gifted with functionless structures ?

Evidences from physiology

Like the anatomy, the physiology of animals also provides illuminating evidence for evolution. Do you remember the endocrine glands in vertebrate animals ? Their products called hormones are the same throughout the vertebrate series. The hormones from the pituitary gland which promote sexual maturity are the same in sea-lion, the cow and in man.

Examination of the blood in different animals has shown that closely related forms have more compatibility in the property of blood than unrelated forms. Thus, the blood of man is more allied to the blood of monkey than that of a sheep, or a horse. Again, the blood of all mammals is more alike than that of birds or reptiles. Various enzymes like the digestive and respiratory enzymes, are similar in many organisms. The chlorophyll *a* and *b* in green algae is the same as that in higher plant, and the same process of photosynthesis operates throughout the plant kingdom. Does it not signify that these have come from a common ancestral stock ?

Evidences from embryology

Fig. 2.11 illustrates the embryos of a few vertebrate animals at an early stage of development. Note that all of them possess certain similar structures like pharyngeal pouches or slits, tail, etc. This similarity of appearance is more marked in closely related forms. Similar resemblance is also noticeable in the larval forms of invertebrates. Darwin, when studying the development of Barnacles, noted this phenomenon. Earlier workers who observed this claimed that the embryos of higher forms resemble the lower forms in appearance. But it was Von Baer, who corrected this view. It was he who put forward the idea that lower forms do not resemble the embroys of higher forms, but on the contrary, the embryos of both higher and lower forms resemble each other closely up to a stage in their development. This view was later extended in 1866 by Haeckel into a doctrine, which states that the development of an individual involves the repetition of stages resembling

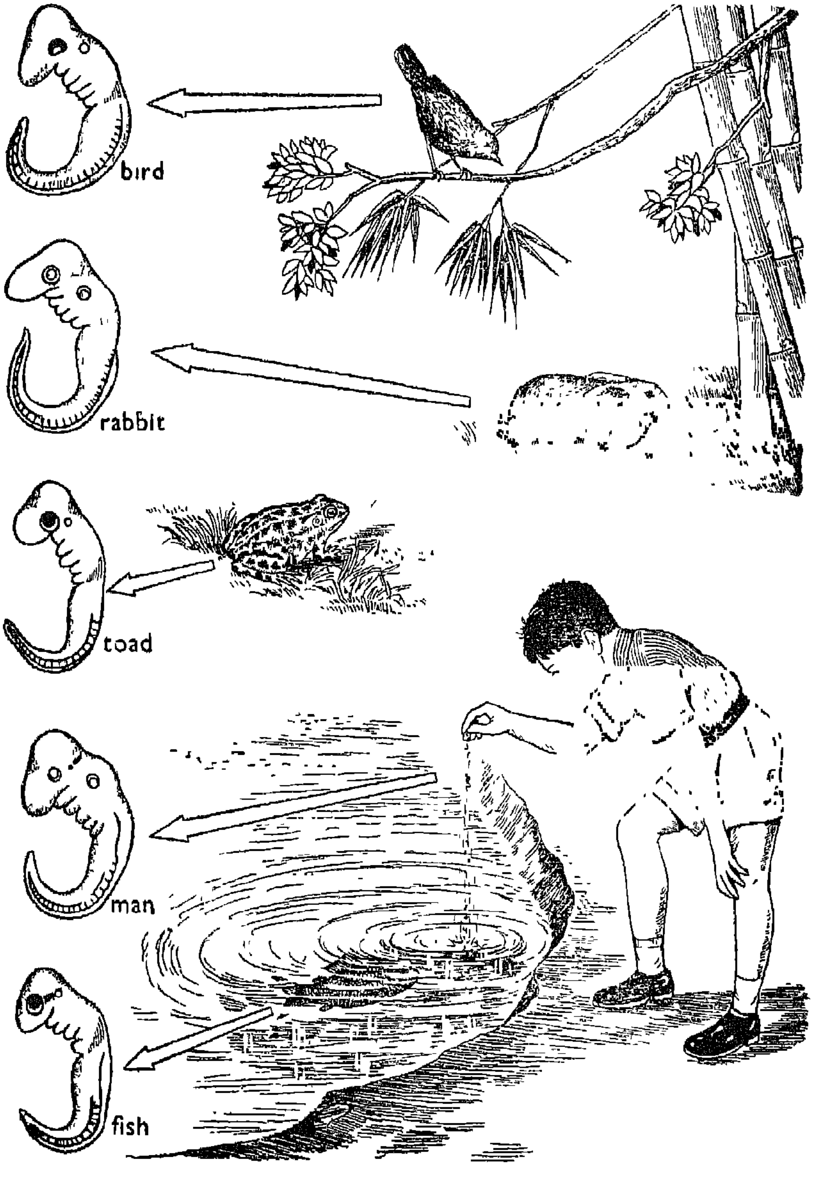


FIGURE 2.11 Embryos of a few vertebrates. Note that the adult forms are markedly different but their embryos resemble closely.

the embryos of its ancestors. The sequence of this is not strictly followed and such repetition is more complete in the earlier stages. This may be briefly stated thus : " Ontogeny is an epitome of phylogeny ".

Evidences from geographical distribution

Biologists have always been puzzled by the manner in which the present day forms are distributed on the earth. So was Darwin. From Lyell's book he learnt that topography of earth's surface has changed. Darwin thought that this may have some relationship with the distribution of ancestors of present day forms. He collected reports of many expeditions bringing information about the distribution of different organisms. Let us discuss a few examples.

1. The well known flowering plant *Magnolia* is seen today in South Eastern United States and South East Asia. How does this plant grow in such widely separated areas ? Again, the *Magnolia* can grow if introduced in other places. From the fossils it has been found that, in the past, *Magnolia* plants were present in most of the regions between their present day distribution. But the climate changed due to glaciation from the north which killed all these plants, except in those places where they are thriving now.

2. The animals of Australia are interesting examples. Australia has the primitive egg laying mammals, i. e., the Duckbill Platypus and spiny ant-eater, primitive pouched mammals like the kangaroos, placental mammals like bats and mice. Many other groups of mammals found in the other parts of the earth are not present there. How can such a peculiar distribution be explained ? It is known that in the past, Australia was connected with the main landmass of Eurasia. Primitive egg laying mammals and pouched animals were present in Australia and also in other parts of the world. Before the rapid increase of placental mammals in Eurasia, Australia became separated from the rest of the land mass. The vast sheet of water acted as a barrier to the ferocious placental mammals which were not able to enter into the island continent. This gave the primitive mammals of Australia an opportunity to flourish and thrive well whereas they became extinct in the other parts of the earth. This view point has been confirmed by the discovery of fossils of egg-laying and pouched mammals from Europe and Asia. Opossums

in South and North America are other living examples to show that primitive pouched mammals actually were distributed throughout the world.

Towards the making of a theory

Let us now scan the highlights of all these evidences :

A.	Geological evidences ...	1. The earth has changed and so have its living inhabitants.
		2. The fossils found in different strata testify to the changes in living forms.
		3. Complicated living forms appeared later than the simpler forms..
B.	Anatomical and Physiological evidences.	1. Closely related forms have similar structural design.
		2. Many organs exhibit modifications from simple to complex.
		3. The presence of homologous structures in different organisms.
		4. The presence of many similar structures even in vestigial state.
C.	Embryological evidences.	1. Embroys of different forms resemble one another.
		2. This resemblance is more prominent in closely related forms.
		3. Repetition of the phylogenetic events is more pronounced in the early stages of embryonic development.

D. Geographical evidences.
1. Present day discontinuity in distribution is due to operation of several factors in the past.
2. A place having a particular kind of environment favours only particular organisms, while other organisms vanish.

These highlights lead us to infer that—

(1) Different animals and plants have changed with time. The present day diversity in the living world is due to these changes. Therefore, they are not the result of special creation.

(2) There is a common ancestry in all organisms which later has given rise to diversity.

Darwin came to a similar conclusion but was caught up with another question. What is the guiding principle of the change ? In other words, what has directed the change ? While Darwin was engrossed in finding out the clue to this problem he came to know from a pamphlet on human population written by Malthus, that human offsprings are produced in a geometric progression but that food and shelter increased in an arithmetic progression. This lead to a struggle for existence among them. As a result increase in population is checked. Darwin wondered whether this is true of other living organisms. He calculated the reproductive rates of various organisms and found that even a slowest breeder like elephant exhibits unbelievable potentiality of reproduction. A pair of elephants produce only 4 to 6 calves in their entire life time. From such a pair, in 1000 years time 20,000,000 elephants may arise. He also realised that the struggle is a reality in the living world. He remembered the competition for sunlight amongst plants in Brazilian forests. He also considered his experience about the breeding of domesticated animals. He bred a number of varieties of domestic pigeons from the ancestral wild rock pigeon. He recalled from his experience that in all such breeding endeavours, in order to get a desired form, man selects some variants and rejects the others. Darwin came to this conclusion after twenty years of hard work. In these twenty years he had established himself well by publishing many original research papers. But when his theory of evolution was ready for publication a dramatic coincidence took place. He received the manuscript of a paper from an English naturalist, Alfred Russell Wallace (Fig. 2.12.), who described the mechanism of evolution independently in the same way as thought of by Darwin. Wallace, who was then working in South-East Asia, sent his work to Darwin for comments. This put Darwin in a very embarassing situation and he preferred to withdraw his paper. Darwin was later persuaded by his friends to change his decision and it is through their efforts that the two works were jointly presented at the meeting of the Linnean Society of London on the 1st July, 1858. Next year, in 1859, the entire work of Darwin was published in the form of a book named, *The Origin of Species by means of Natural Selection.*

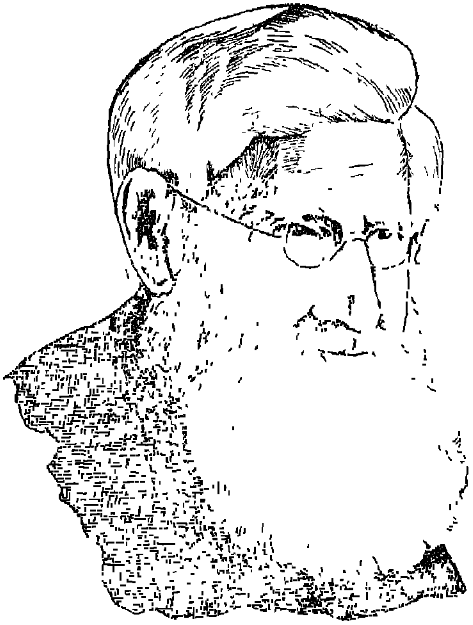


FIGURE 2.12 Alfred Russell Wallace (1823-1913).

Darwin's theory and its impact

Darwin observed that all living forms increase prolifically and compared to such a rate of increase, the amount of food and habitable space remain constant. He also noted that no two offsprings are exactly alike. This he called *variation.* According to him, this prolific production of variations results in :

A. The struggle for existence

It involves severe competition. This struggle may be within the members of the same species or between different species or against natural factors. It leads to—

B. The survival of the fittest

Only those forms which are well suited to the prevailing environment can survive and thus get an opportunity to produce the next generation. It is possible because of—

C. Natural selection

Nature enables the fit forms to survive and rejects the unfit forms. This is the mechanism which operates during the evolution of the species. In this way the present day species of animals and plants have originated from their now extinct ancestors.

Figure 2.13 Jean Baptiste Lamarck (1744-1829)

The success of Darwin lay in the accumulation of enormous evidences from various sources in favour of the evolutionary concept.

Of all the other evolutionary theories which were published before Darwin, the most important was the one proposed in 1809 (the year Darwin was born) by a French naturalist, Jean Lamarck (Fig. 2.13). Lamarck, after studying different species of fossils, brachiopod shells and characteristics of various other organisms, came to the conclusion that diversity in living forms is not the result of special creation. In other words, species are mutable. According to Lamarck's view :

(1) All organisms in each generation modify or acquire some new characters by use or disuse of its parts depending on its specific need.

(2) These acquired characteristics are inherited by the next generation. According to Lamarck, ancestors of present

day giraffes were short-necked. In order to reach foliage in higher branches they stretched their neck as much as they could. This resulted in a slight increase in the length of the neck. This acquired feature was passed on to the next generation which also stretched their necks and some more elongation of the neck occurred. Due to the cumulative effect of several generations, the present day long-necked giraffes were produced.

Lamarck's theory obtained the hardest blow from a German Zoologist called Weissmann (Fig. 2.14). He demonstrated that if the tail of a mouse is cut it never produced a tailless mouse. He repeated this experiment for several generations, but everytime the new-born mice had a normal tail. This experiment disproved the possibility of inheritance of acquired characters. If acquired characters are not inherited, how is it possible to explain the origin of present day giraffe ? As you are now familiar with Darwin's view, try to explain it in the light of natural selection

FIGURE 2.14 August Weissmann (1834-1914).

The immediate impact of Darwin's theory was great. Some believed it, others did not. Numerous discussions, arguments and counter-arguments followed, but the weight of Darwin's evidence was so astounding that it survived many odds. Darwinism has been criticised from many angles, valid and invalid. Some prejudiced critics held that Darwinism indirectly means " might is right ". The ancestral relationship was mistaken as a direct line of descent. Many people also considered it a disgrace to imagine that man originated from the monkey. They failed to realize that all living forms are related to each other or are remote cousins. Though Darwin realized that changes had occurred, he was unable to explain how these *changed traits were transmitted from* *one generation to the next.* The main reason for this, as it has already been said, was the lack of knowledge of genetics, physiology and palaeontology in his time. Only later findings enabled biologists to strengthen Darwin's view.

Mechanism of evolution as known today

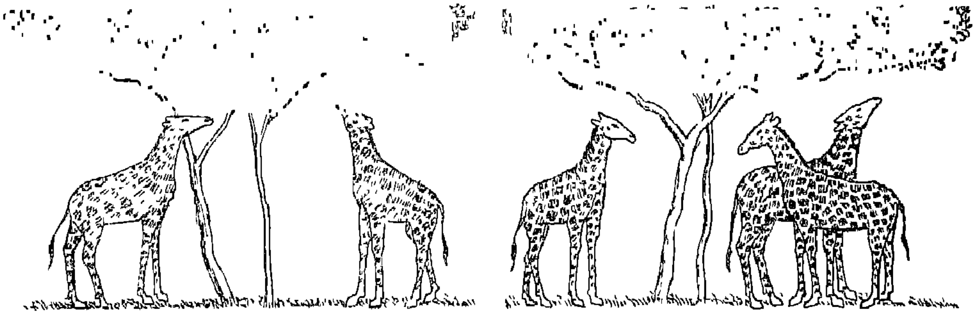
Darwin realized the extent of variation and its significance in evolution, but he had no idea about the factors which controlled characters. You have learnt about Mendelism in an earlier chapter. Now you know that characteristics depend upon genes and a particular constellation of genes (genotype) controls the characters of an individual. Our present knowledge about heredity tells us that a single phenotypic character may be controlled either by a single gene or by multiple genes. Different phases of sexual reproduction bring about new combinations of genes, i. e., new genotypes, which result in new phenotypes of variants. We may once again recapitulate the genetic basis of variation.

1. *By crossing over* of homologous chromosomes during the time of gametogenesis.
2. *By random assortment* of homologous chromosomes at the metaphase stage of meiosis.
3. *By outbreeding*, i. e., union of gametes from individuals having different genotypes.
4. *By mutation*, i. e., production of new alleles which give rise to new characters.

Recently it has been realized that evolution does not occur at the individual level. On the contrary, it is necessary to consider the genotype of the entire population for initiating an evolutionary change.

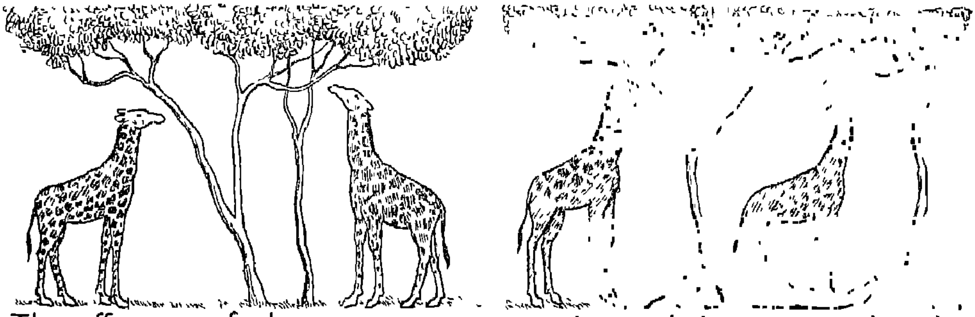
Once the cause of variation is known, the other two facets of natural selection—struggle for existence and survival of the fittest require a new interpretation. Let us examine how the struggle operates.

1. Take a 15 cm pot containing soil or saw dust.
2. Sow 50 paddy or wheat or pea seeds.
3. Take proper care that they get usual supply of water and sunlight.
4. After a fortnight, note how many seeds have germinated.

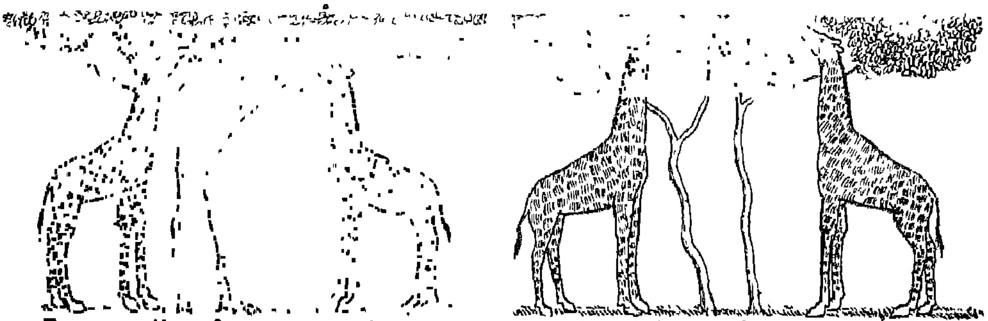


ancestral short necked giraffes frequently stretched their necks to get the leaves of the trees.

This resulted in slight increase in their neck



The offspring of the next generation inherited this increased neck. They continued to stretch further and this resulted in lengthening of the neck.



Eventually after several generations this effort of stretching gave rise to present day long necked giraffe.,

FIGURE 2 15 Evolution of the Giraffe.

5. Fill in the following proforma with the results of your experiment.

No. of seeds sown	*No. of seedlings after 15th day*	*No. of plants which attain reproductive stage*

Did you notice here any direct aggressiveness among the plants ? Why then in spite of uniform conditions, did some grow while others failed ? How can we consider the surviving plants as more fit than the others ? It is evident that "struggle" means competition and "fitness" depends upon the following factors.

1. *Adaptation*:—It is the ability of an organism to survive until it attains its reproductive maturity. Any character of the individual that enhances the chance of its survival promotes adaptation. Such an adaptation may be structural, physiological or behavioural, but usually a combined effect of all. The marvellously adapted body of the stick insect or leaf-butterfly would have had no survival value, if these insects had not developed structural features simulating the appearance of leaves and dry branches and the habit of remaining motionless.

2. *Sexual selection*:—The ultimate success of fitness depends upon the ability to reproduce and for this reason, in the higher forms, sexual selection plays an important role. It has been noted in plants and animals that even a single trait gets preference for reproduction.

How, within a short period of time, a certain form can be eliminated and another selected was elegantly shown in 1950 by Sheldon and Elizabeth Red through an experiment. They kept equal number of red eyed males, red eyed females, white eyed males and white eyed females of fruit fly (*Drosophila*) in a culture bottle. In another bottle they kept only red eyed males and red eyed females and in a third, only white eyed males and white eyed females. The latter two served as controls. After *following* 25 generations, they found that the control bottles contained only the progenies of red and white eyed fruit flies respectively. But in the bottle originally containing equal numbers of mixed population, no white flies were present. It demonstrated that red eyed males were selected not only by the red eyed females but also were found attractive by the white eyed females.

3. *Parental care:*—It may appear that index of fitness is the ability in producing offsprings. But that is not all. If the offspring is sterile (as in mule), it will serve no purpose in the continuity of species. The death of the offspring before it could reproduce also would be deadly to the race. Many organisms, avoid this danger and through instinct, provide some sort of care to their eggs and offspring. Such parental care is especially developed in birds and mammals. Many organisms with no parental care compensate by producing eggs in prolific numbers, such that a part of it can at least reach the reproductive stage. In order to afford proper care, organisms with parental care have lesser number of eggs or offspring at a time. Therefore, the criterion of fitness in evolution is how the family is at the end and not at the beginning.

How does a new species emerge ?

In the light of our recent knowledge, how then does a new species originate ? Let us examine the finches (Fig. 2.16) which Darwin observed and discuss their probable mode of speciation :

1. When the ancestral seed-eating finches from the main land reached the Galapagos they faced no competition from other birds or enemies.
2. They reproduced and raised forms having great variability. As there was no competition, all the variants (phenotypes) survived. Some variants explored other food habits.
3. Some of these variants were isolated. You must have noted that plants and animals usually breed within close vicinity. So did these isolated variants. Their inbreeding produced a sub-population which, due to isolation, did not obtain any chance to breed with the

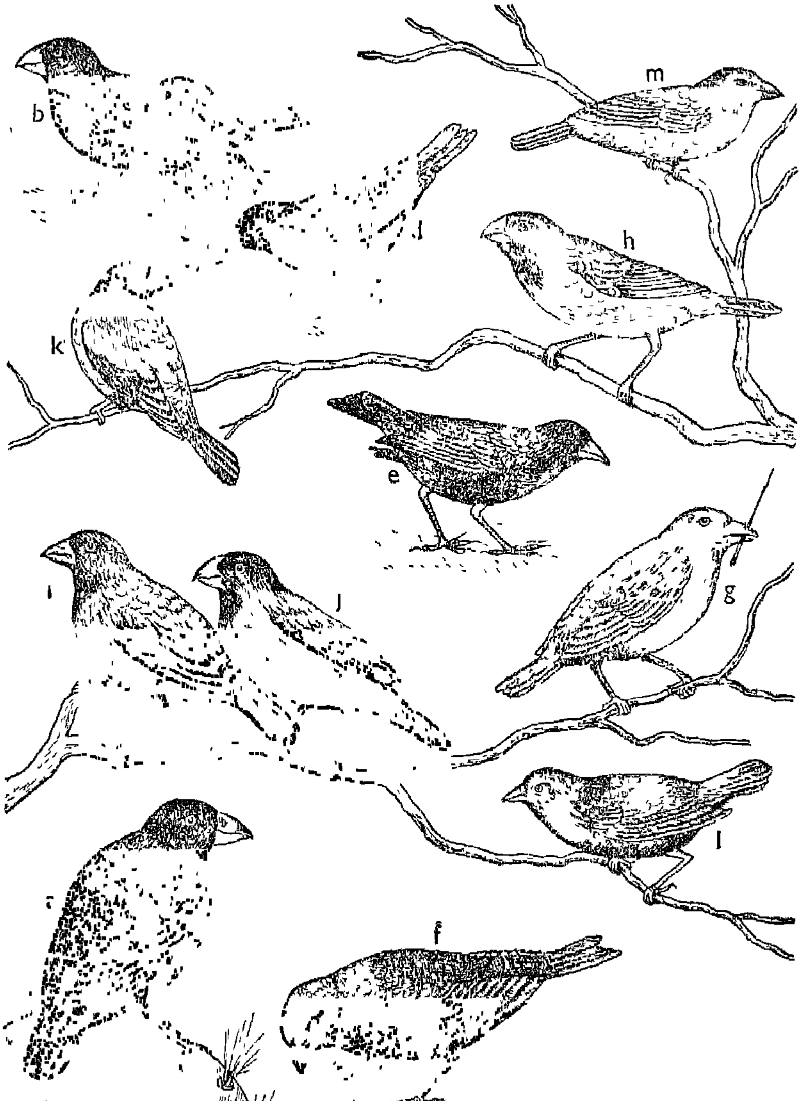


FIGURE 2.16 Darwin's finches.
(*a*) Larger cactus ground finch (*b*) Large ground finch (*c*) Medium ground finch (*d*) Cactus ground finch (*e*) Sharp-beaked ground finch (*f*) Small ground finch (*g*) Woodpecker finch (*h*) Vegetarian tree finch (*i*) Large insectivorous finch (*Camarhyncus pauper*) (*j*) Large insectivorous finch (*Camarhyncus psittacula*) (*k*) Small insectivorous tree finch (*l*) Warbler finch (*m*) Mangrove finch.

main stock or any other sub-population. Thus closely resembling genotypes were produced.

4. After a gap of several years these populations reunited with the main stock or with another new population like them. But the two groups failed to breed with each other. The chief reason for this failure is the inability of one sub-species to produce sexual excitement in the opposite sex of another sub-species. So the two sub-species remained separated.
5. After reunion, when these two sub-species remained reproductively separate, they diverged further because of competition. The divergence was greater when competition was severe.
6. In the case of Darwin's finches, such changes might have happened along several lines ; thus several new species were formed some of which were fruit eaters, some grain eaters, and others wood peckers, etc. The production of several such new species in different lines from a common ancestor is called *adaptive radiation*.

It is estimated that ancestors of mammals were small insect eating forms. They were insignificant in number at the time when the mesozoic reptiles were dominating the earth. After the extinction of the giant reptiles, the mammals had the earth almost free from competitors, a condition almost comparable to that which the ancestors of finches of the Galapagos found. Like those finches, the ancestral mammals reproduced and raised forms of great diversity. Most of the variants (phenotypes) got a chance to survive and they explored almost all sorts of environments on the earth (Fig. 2.17).

Is evolution still in progress ?

Organic evolution is a process of change of the living world as it floats over the ocean of time. It is thus evident that the evolutionary processes are still in operation. But if we seek the evidences of this from our surrounding reality we find that they are not as striking as they were when we studied the life of the past. For instance, the distinguishing characteristic of African and Indian elephants have remained the

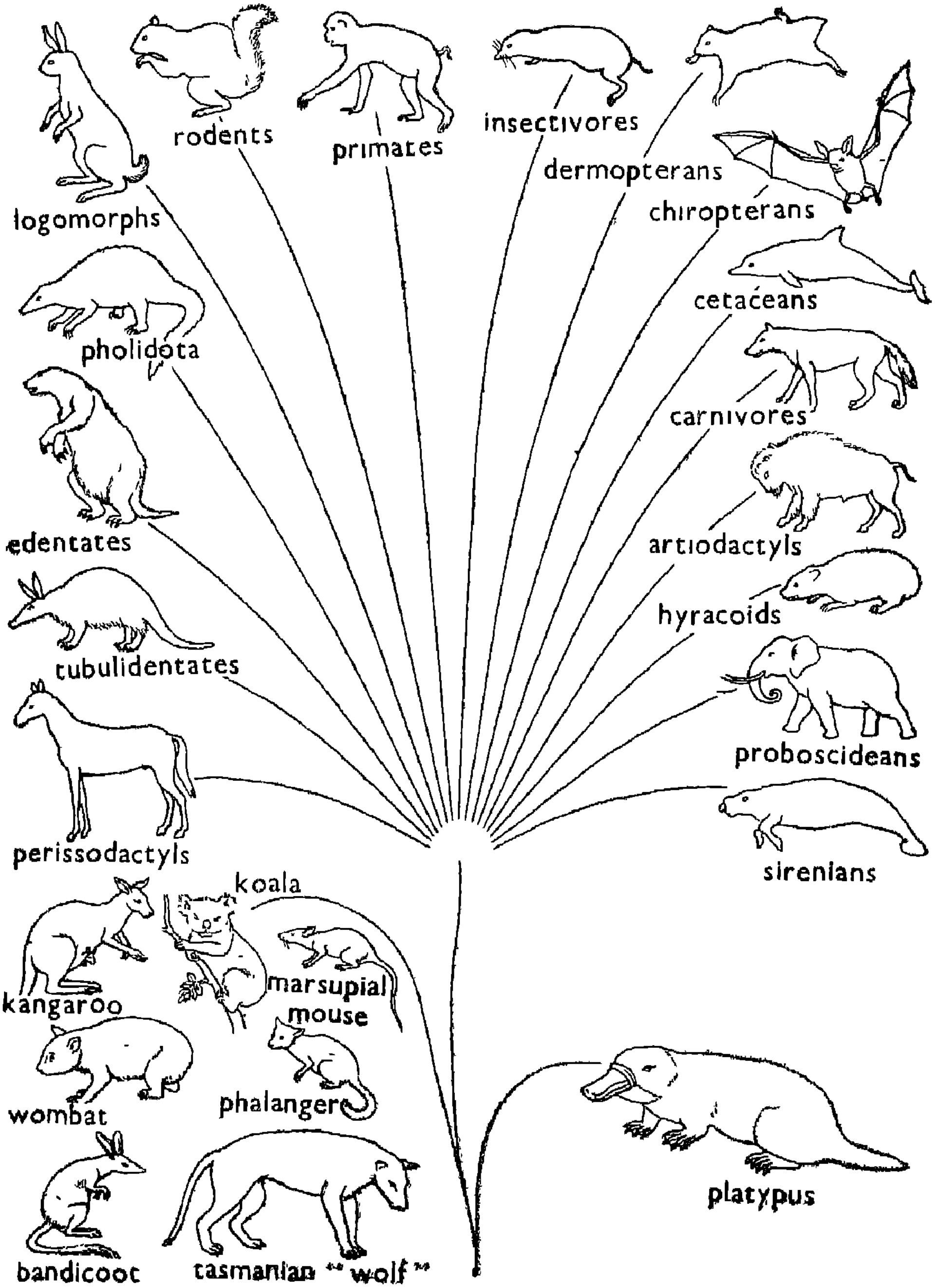


FIGURE 2.17 Adaptive radiation in mammals.

same as they were in Darwin's time. The finches which Darwin observed in the Galapagos exhibit even today the same old differences. Evidences are available but they are not so striking as we have seen in the past events. The reason is that evolution is a slow process, and that the changes which led to the present day diversities operated for several million years. As compared to that, a few hundred years are hardly significant. Let us analyse a few instances which are recent evidences of evolution.

Example one:—Before 1848, the most common peppered moth in the countryside of England was mostly light-coloured (Fig. 2.18). Such a body colour enabled them to adapt well with the light coloured background of the environment (rocks, walls and barks). After the influx of industry in the early 19th century, the deposition of soot and tar changed the landscape from light to dark. Strangely enough, with the changing shade of background the peppered moth with dark colouration became preponderant.

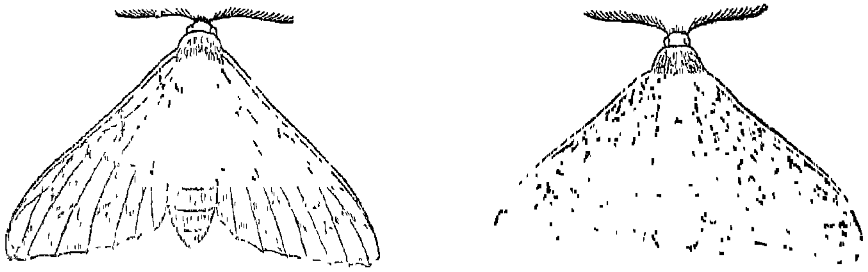


FIGURE 2.18 Light and dark coloured Peppered Moth.

Example two:—Various antibiotics like penicillin or streptomycin are used against bacterial infection. Such antibiotics destroy bacteria like the *Staphylococcus* and other forms. But recently, in several instances, it has been recorded that the bacteria can resist the action of antibiotics. It means that some new changes have taken place in those bacteria and resistant types have evolved.

Example three:—Formerly mosquitoes were easily killed by DDT (an insecticide). But now we find that new strains of mosquitoes are often resistant to this insecticide.

The following assumptions may be set out to explain the above examples. You may select on the basis of your understanding about the mechanism of natural selection, the particular explanation which seems logical to you.

1. As the environment changed, all the existing light coloured peppered moths changed their pigment pattern from light to dark.

or

From soot or tar certain chemicals affected the peppered moth. The chemicals might have produced certain effects which were transmitted to the next generation and the moths became black.

Peppered moths always produced some dark varieties (may be in much lesser number). When the background was light coloured, the light coloured moths, being able to remain inconspicuous, evaded their enemies and thus survived. But the dark coloured forms being prominent in such environment were easily captured by the birds and thus were eliminated. But when the surroundings changed to dark, these dark variants escaped the enemy, whereas light coloured forms were easily killed. Thus with the change in the environment, light coloured variants were eliminated and dark coloured forms became predominant.

2. All bacteria developed certain means to resist action of antibiotics.

or

In a population of bacteria though most were killed by the antibiotics, some variations survived. These resistant forms multiplied and gave rise to a generation which were resistant to antibiotics.

3. Mosquitoes developed some mechanism to neutralise the effects of DDT.

or

New kinds of mosquitoes, which were able to resist DDT, came from some other place.

or

Though all the mosquitoes were killed by DDT, a few survived. Those variants probably had a slightly different genetic make-up which permitted their metabolic system to tolerate DDT more than the others. As other variants died, only these variants multiplied and gave rise to a generation which was resistant to a certain concentration of DDT. In this way, in successive generations, only the forms which were able to cope up with the action of DDT, were able to survive. Finally, only one stock could survive which was completely resistant to this insecticide.

Evolution of man

That man is a descendant of ape-like ancestors, as interpreted from the Darwinian concept, was distasteful to some of Darwin's contemporaries. The story says that on hearing Darwin's idea, a lady cried "Descended from the apes ; Oh dear, we will hope that it is not true. But if it is, let us pray that it may not become generally known". To her, it was terribly humiliating to be related, however distantly, to an ape. But the views of Darwin became rather generally known, and most people accepted the idea.

It is now believed that man came from an ancestor who was common to monkeys and apes. The same ancestor in turn arose from a stock from which other mammals also originated. Some of the descendants of ancestral insect eating mammals preferred to live on branches. Such a life demanded two important changes namely a grasping hand and a binocular vision. These two features helped in moving safely through the branches and enabled the organisms to judge the distance of the enemy. Lemurs and Tarsus monkey exhibit almost similar features. This ancestral beginning gave rise to three different lines—new world monkeys, old world monkeys and the ancestors of apes and man. The monkeys evolved to live better on branches but the ancestors of apes and man evolved to live on the ground. The reasons for this were probably (1) increased competition on branches and (2) the reduction of forest area due to glaciation. The ground dwelling forms required the following body changes : erect posture, lengthening of the fore limbs, perfection of the binocular vision and absence of a tail. The line which gave rise to apes, spent most of the time on branches and occasionally came down to the ground. They either walked on all fours or stood erect with the support of branches and the fore-limb. Among the apes, the Gorillas show a complete ground dwelling habit. But it still dwells near the forests with almost complete adoption of bipedality.

The line which gave rise to man evolved further. The forelimbs free from the job of carrying body weight, were utilized further in various ways. But the most important changes occurred in the cerebral cortex region of the brain, which gave him the power of reasoning and to memorize the past happenings more efficiently than ever. The total effect of these changes has enabled man to reach his present state. All these happened within the last one million years or so.

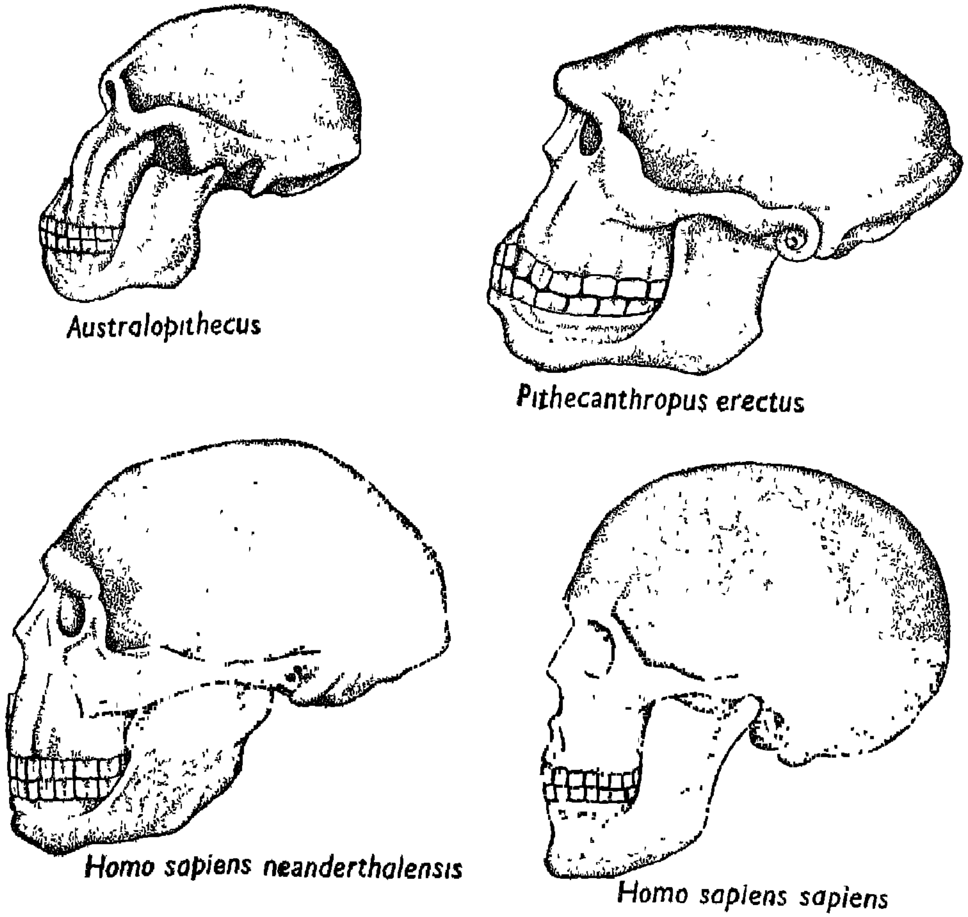


FIGURE 2.19 A. Skull of *Australopithecus*. Its skeletal structure has given it a strong claim to be considered as a missing link between apes and man.

B. Skull of *Pithecanthropus erectus*. Note that the skull bones are thicker than those of modern man. The forehead slopes backwards from the prominent, continuous eyebrow ridges. The lower jaw is large and bears powerful teeth, but the chin is absent.

C. Skull of *Homo sapiens neanderthalensis*. Note that the skull is made up of large bones but the eye-brows are less prominent than *Pithecanthropus*. The forehead is retreating and the lower jaw is heavy.

D. Skull of *Homo sapiens sapiens*. Note that the cranial capacity is much increased but that the bones of the skull are not thick.

Unfortunately, due to lack of complete fossil evidence, the full story of human evolution is not yet precisely known. Both the lines of descent, that of man and ape, probably originated from some chimpanzee-

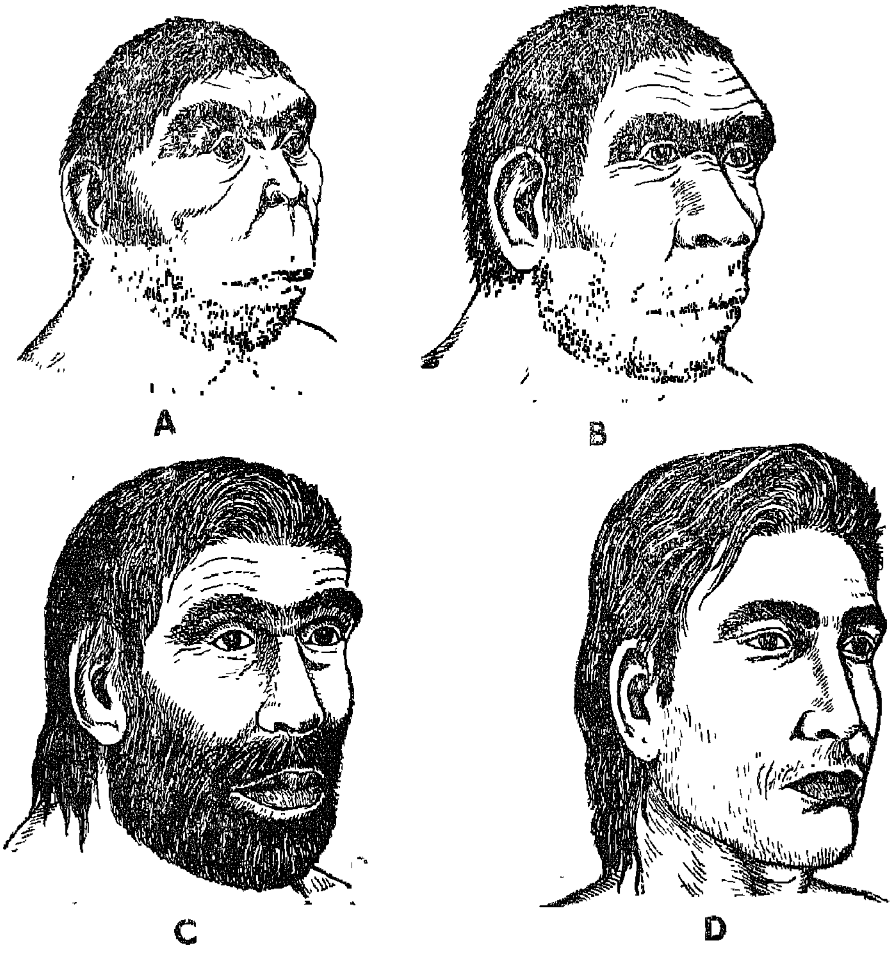


FIGURE 2.20. Reconstruction of heads on the basis of skull structures of Prehistoric men.

A. *Australopithecus.* One group of scientists consider it as the ancestor of mankind, while another group feels it as only a "hunting", flesh-eating shell-cracking and bone-breaking "ape"

B. *Pithecanthropus erectus* This fossil was first obtained from Java and this short sized (5 feet) form was intelligent enough to fashion and use stone tools.

C. *Homo sapiens neanderthalensis.* These forms lived in Europe, Western Asia and North America These short and ruggedly built forms had a special organization and they attained higher cultural level.

D. *Homo sapiens sapiens.* **Present day** man.

like forms. The oldest known fossil indicating the common ancestry of man and ape, is that of the Proconsul which lived nearly 25 million years ago. A number of fossils like *Dryopithecus* and *Ramapithecus* are found in the Siwalik beds of India and are believed to possess both human and ape-like features. The fossils which are believed to be in the direct line of human origin are *Australopithecus*, *Pithecanthropus erectus* (Java man), *Sinanthropus pekinensis* (Peking man) and *Homo sapiens neanderthalensis* (Neanderthal man). Fig. 2.19 and Fig. 2.20 will give you an idea about these prehistoric men.

Emergence of Modern Man

Some 75,000 years ago Neanderthal man was overrun by another

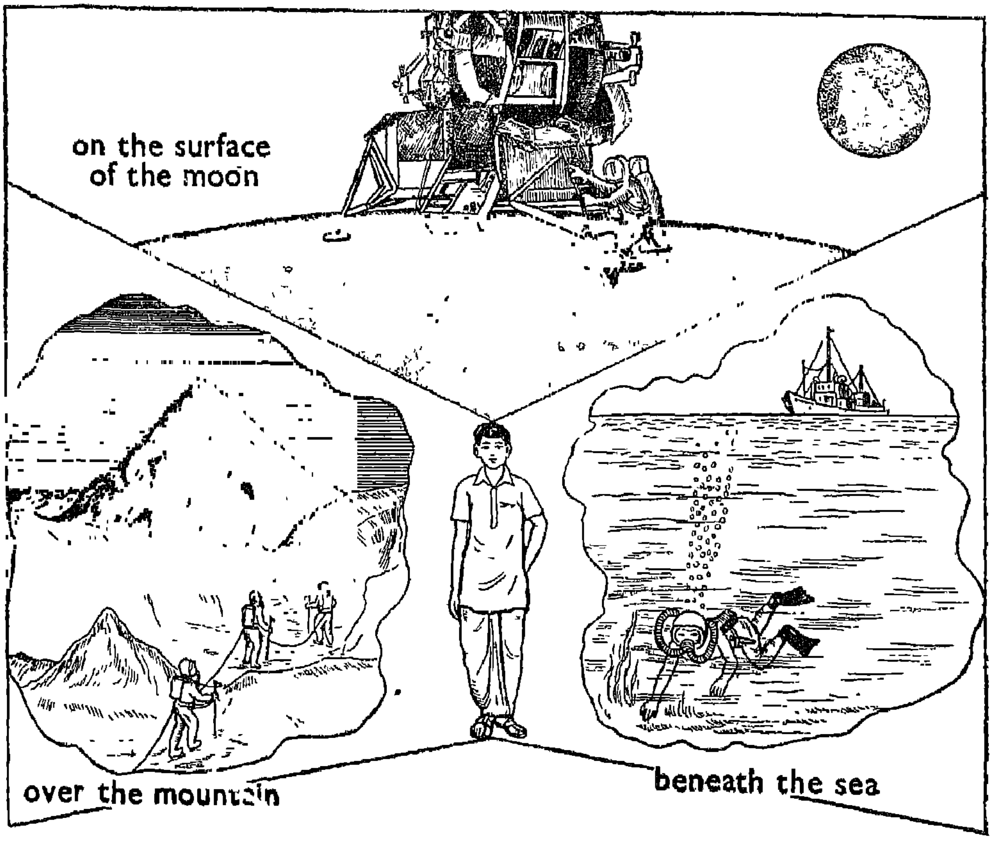


FIGURE 2.21 An artist's impression of the ability of man to conquer his environment which is the secret of his success.

race, which, to judge from its bones, was like the modern man, *Homo sapiens sapiens*. The tools they used were expertly made. The earliest known man called Cro-Magnon attained a height of about 1.8 m and his brain was about 1650 cc in volume. Any way, from this time on, the rest of the world was inhabited by *Homo sapiens sapiens*.

Where did the first man originate ? The answer is very complicated, speculations concerning it are various, but no convincing conclusion is yet in sight.

Man is no doubt a product of organic evolution but he is also unique in a purely biological sense. Compared to other mammals his structural adaptation is very poor. He cannot bite effectively, he cannot run swiftly and does not have an efficient protective covering on his body as have the other animals. His eye sight is feeble, his powers of smell and hearing are poor. But still he has outraced the others. The secret of his success is in his ability to conquer his environment through brain power (Fig. 2.21). He can live in any part of the globe, he can dive down the ocean, can stand on the summits of mountains and can walk on the moon.

CHAPTER III

MAN AND NATURE

Man is the most highly evolved and successful of living creatures. He is quite unique in several respects. The success of man in the world today is due to his ability to create and control his own environment. In the early stages of civilization he would have faced the problems of obtaining food, and of protection against diseases, etc. Man from the very beginning, struggled hard to overcome these problems and to conquer nature for his better sustenance. We will see presently how far he has been successful.

Fight against hunger

(a) Procurement of food by early man

The life of early man was precarious and uncertain. He had to seek his food daily. If he did not get anything to eat he would starve and die. Food was also scarce and was often difficult to collect except in some areas which were very productive. His food consisted mainly of roots, tubers, seeds or fruits, small animals such as rodents and perhaps fish. He also hunted large animals. For this he had to go in the company of his fellow-beings and kill the animals with stones, stone implements or sticks and in the later stages with crude arrows and spears. In this way of life there was always a risk of being wounded and bled to death. People had to wander from place to place in search of food. Out of sheer necessity, thus, they had to lead a nomadic way of life.

Even today there are many people who live this kind of life such as the aborigines of Australia, the pygmies of Central equatorial Africa, the malapantarams and chenchus of South India.

(*b*) *The cultivation of plants and domestication of animals*

Man was at the mercy of his environment till 10,000 years ago. The cultivation of plants and the domestication of animals started probably independently in different regions of the world at different times. In the following Table only four major centres of origin are presented, keeping in view the important plants and animals :

TABLE 3.1

Sl. No	*Important plants and animals*	*Centre of origin*
1	*Rice, Orange, Banana, Tea, Sugarcane, Yam, Pepper, Chicken, Dog, Pig.*	*South Eastern Asia.*
2	*Wheat, Barley, Rye, Oats, Apple, Grapes, Cow, Sheep Goat, Horse.*	*South Western Asia.*
3	*Bean, Corn, Chillies, Pumpkin, Turkey*	*Mexico and Central America.*
4	*Tobacco, Potato, Tomato, Pineapple, Guinea-pig, Llama.*	*South America.*

The cultivation of plants and domestication of animals are linked with a settled way of life. The fishermen were the first people who led a settled way of life and probably they had better opportunities of starting cultivation. Probably they had better chances of observing the plants growing from the refuse around their habitations which invariably contained the cast off, cut ends of the tubers and some seeds.

When man took to cultivation he had not only learnt how to get a regular supply of grains but also had the wisdom to store surplus produce for the lean months, which assured him and his clan of a continuous supply of food grains. This gradually paved the way for the development of agriculture and the barter trade system.

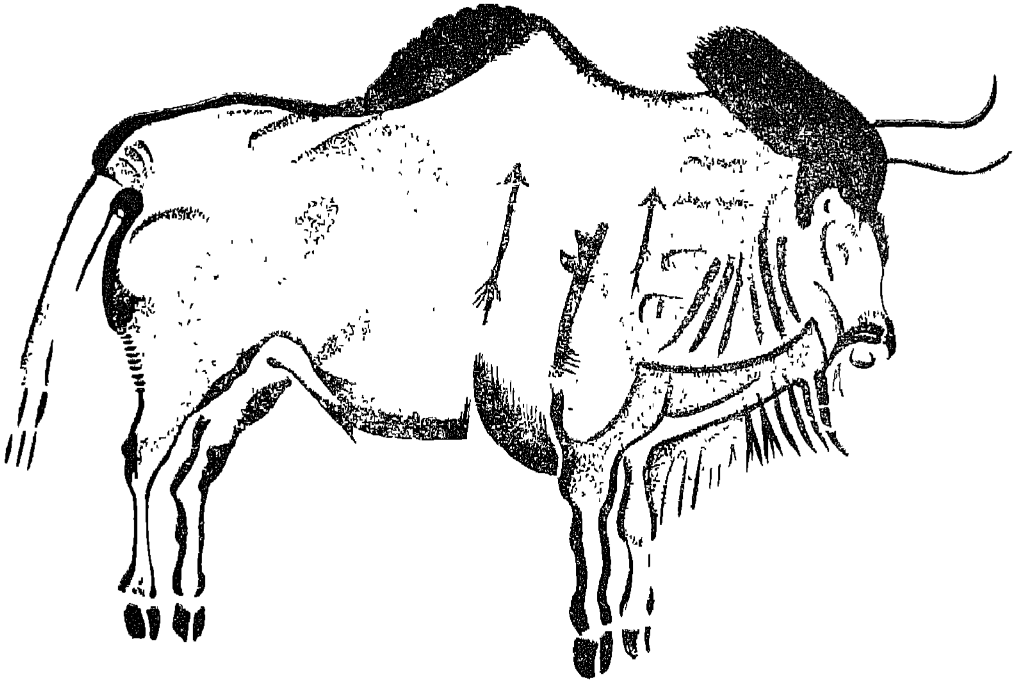


FIGURE 3.1 Prehistoric cave painting of a bison pierced by arrows.

The dog was perhaps the first domesticated animal. The early man used dogs for hunting and also as a source of meat. Settled community life and farming probably led to the domestication of other animals such as cattle and sheep.

With the progress of agriculture and the domestication of animals man gradually gave up hunting and started leading a more settled life which saved him from the risk of wandering about. Obviously with the secured life there was some increase in the population and man attempted to use more and more plants and animals to meet the increasing demand of food.

(c) *Improvement of cultivated plants and domesticated animals*

Early man possibly had a fair knowledge about the differences in vigour amongst the individuals within a given species. He preferred the healthiest and best individuals for the perpetuation of the progeny.

He selected good fruits and seeds of crop plants for sowing and similarly the best animals for breeding purposes. Such a selection made by man is known as 'artificial selection'. This enabled man to maintain a healthy lineage of plants and animals for centuries.

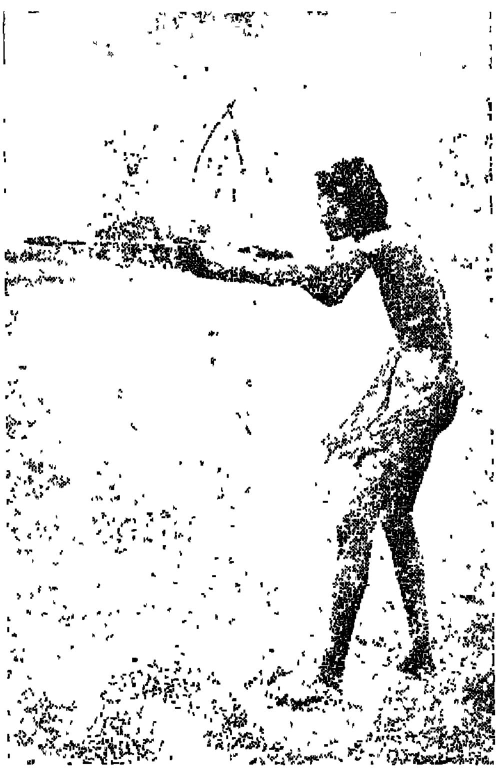


FIGURE 3.2 Aboriginal (a chenchu) hunting with bough and arrow (Courtesy : Tribal Welfare College, Andhra Pradesh).

The methods employed by early men in the maintenance of healthy stock of plants and animals have further developed in recent times in the light of the knowledge gained by Mendel's laws of inheritance. Many new and desirable varieties of plants and animals have thus been obtained, particularly during the last four or five decades.

Using the knowledge of hybridization, mutation, polyploidy and vegetative propagation, plant breeders developed a number of improved and healthy strains of plants. The hybrid corn, Coimbatore sugarcane, the Mexican dwarf wheat, I. R. 8 and I. R. 20 rice are a few examples of newly developed varieties. The yield of maize, wheat, rice, sugarcane and cotton have nearly been doubled or even trebled in recent years. Besides these, a number of vegetable crops such as sweet potato, tomato, peas, and fruits like grape, banana and coconut have been developed. In evolving new strains, the plant breeders try to incorporate the useful characters such as greater yield, superior quality, resistance to diseases, endurance of drought conditions and response to fertilizers.

In the present century, the animal breeders also have made a

FIGURE 3.3 Aboriginals (chenchus) digging out edible roots and tubers with wooden sticks (Courtesy : Tribal Welfare College, Andhra Pradesh)

remarkable progress in developing cattle with higher milk yield or meat content, and fowls with greater and larger egg laying capacities. An important method now adopted widely by cattle breeders is the artificial introduction of sperm of animals with desirable hereditary qualities into the females. This method is known as ‘ artificial insemination ’.

The above technique employed in the improvement of the stock of plants and animals have not been uniformly utilized in different countries of the world. There is much scope for further exploitation of these techniques especially in developing countries like ours.

(*d*) *The food problem in India*

The fact that we import millions of tonnes of food grains every year from other countries indicates that there is a shortage of food in our country. Our country is mainly an agricultural one and although

60-75 per cent of the population is engaged in agriculture, we are still not able to meet our food requirements. What is this due to ?

TABLE 3 2

The average cereal yield and fertilizer consumption in some countries in the years 1950-51 and 1960-61

Country	*Cereal yield kg. per hectare*		*Fertilizer consumption kg. per hectare*		*Increase in kg per hectare*	
	1950-51	1960-61	1950-51	1960-61	*Yield*	*Fertilizer*
India	650	830	0.5	2.5	180	2.0
Japan	2930	4110	153.0	303.7	1180	150.7
Netherland	2810	3750	416.8	456.1	940	39.3
Taiwan	2230	3010	94.3	203.8	780	109.5
U. K.	2230	3130	111.6	180.2	740	68.6

(*Data from*: *Feeding India's Growing Millions*, *Sukhatme* 1965, *Asia Publishing House*)

Further efforts to improve the food situation are in progress. A good number of research laboratories have been established throughout the country in order to investigate the methods of improving food production and advise the farmers about the merits of their application. This research and the consequent guidance have proved to be very useful. For example, the Punjab farmers achieved miraculous success by using ' double ' and ' triple dwarf seeds ' and improved agricultural methods. In Ludhiana district, during the year 1967-68 the average yield of wheat was 4,730 Kg. per hectare, a figure approaching the world record yield of Netherlands. Food grain production increased likewise in several states of our country and this marks the commencement of the ' Green Revolution '.

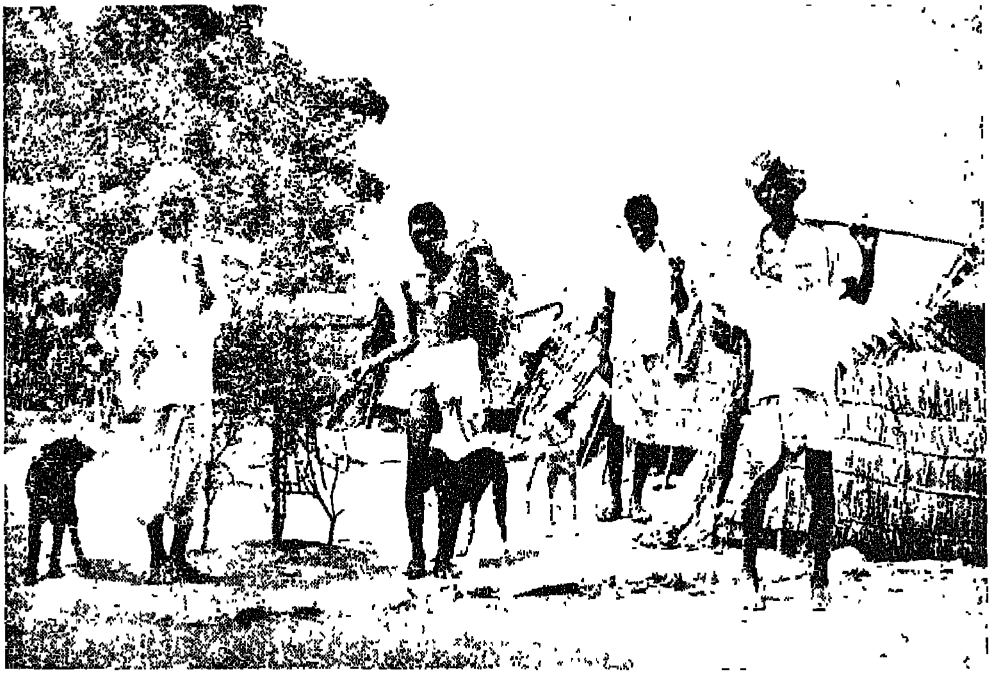


FIGURE 3.4 Aboriginals (Mandulas from Andhra Pradesh), a semi-nomad tribe still in hunting and food gathering stage with traps for capturing monkeys. (Courtesy: Tribal Welfare College, Andhra Pradesh).

At present we rely for our food mainly on a limited number of land plants and animals. As you have learnt earlier, the ocean occupies more than two-thirds of the surface of the globe. Besides fishes and other animals, they support a large number of useful seaweeds. No serious attempt has been made so far to make use of this wealth. Perhaps proper methods of farming and scientific exploitation of the sea would be one of the most promising solutions to our national food problem.

Fight against disease

(a) *Early concepts of disease and its cure*

The life of early man was precarious and full of natural hazards. On account of this he seldom lived up to a ripe old age.

The primitive people had different concepts about life and wrong notions regarding the cause of diseases. The ancient Egyptians believed

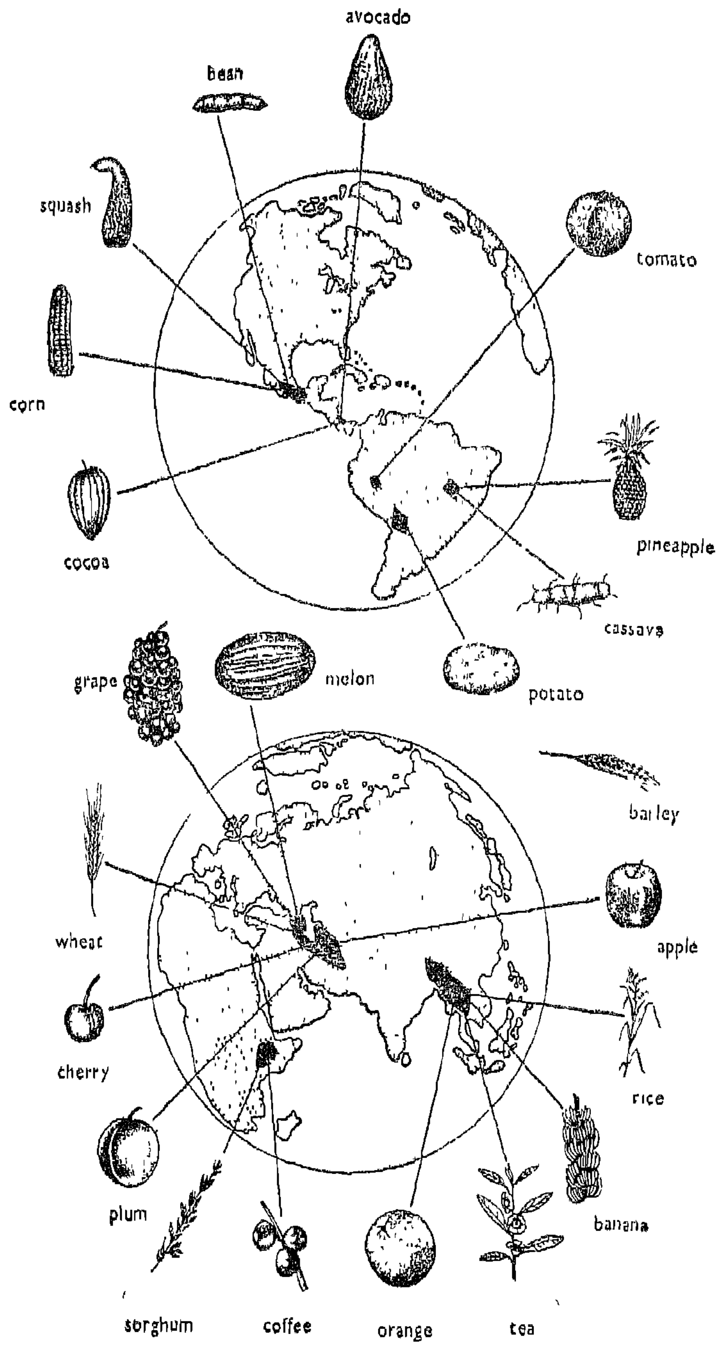


FIGURE 3.5 Major centres of geographic origin of some important cultivated plants.

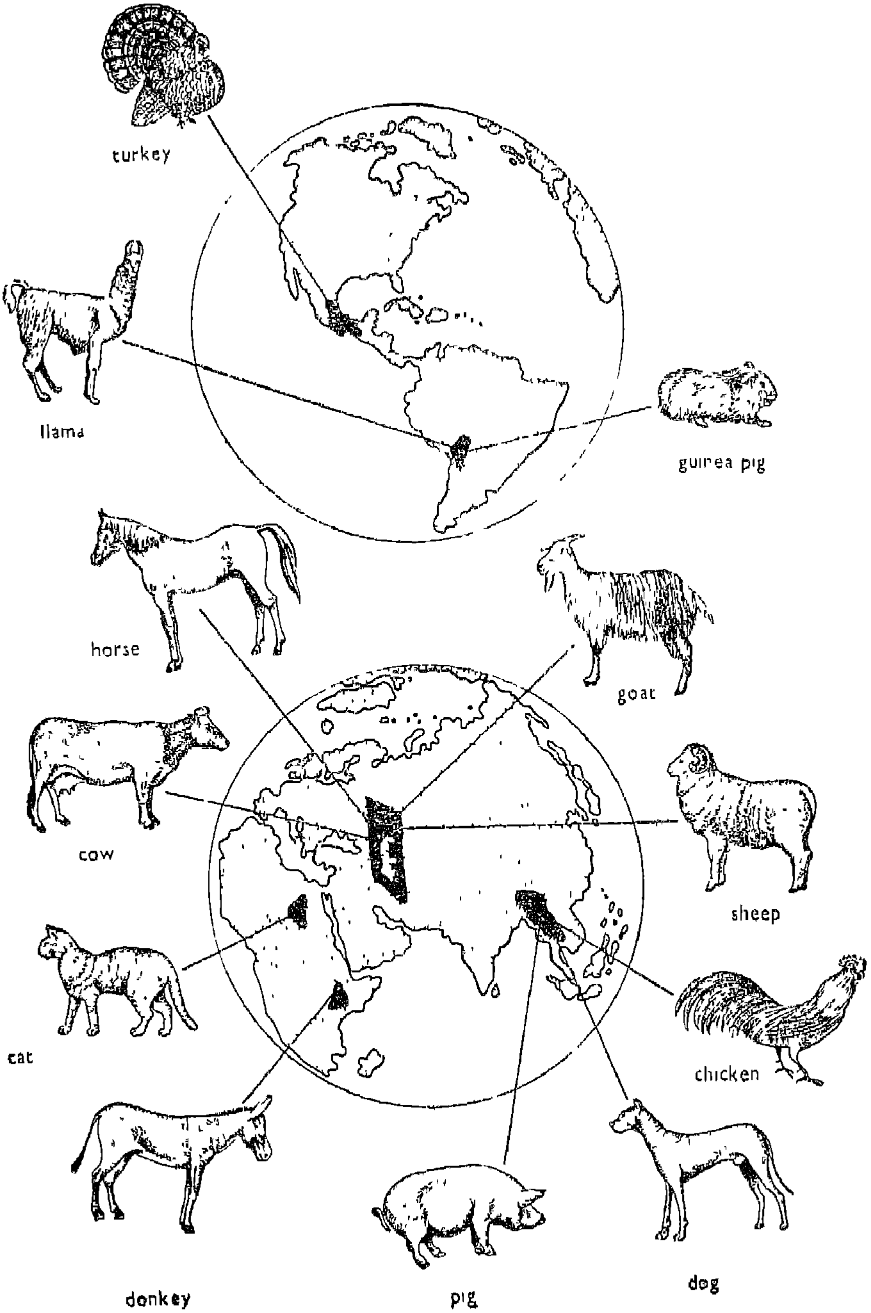


FIGURE 3.6 Major centres of geographical origin of some important domesticated animals.

that man was immortal and that if no accidents occurred, life could prolong indefinitely. The primitive people likewise considered diseases to be supernatural in origin. They thought a person became ill either on account of his sins or under the influence of evil spirits. Even today this type of superstition is common in primitive societies and they attribute the prevalence of most of the contagious diseases such as cholera, small pox and chicken pox to similar causes. To appease the anger of evil spirits they sacrifice animals, such as buffaloes, goats, fowls, etc.

FIGURE 3.7 (A) A triple dwarf wheat variety developed at IARI, New Delhi.

However, Hippocrates, a great physician pointed out as early as 400 B. C. that diseases are due to natural causes. He showed a very sound analytical approach to the understanding of diseases and also suggested measures to avoid their occurrence. This is the reason why he is rightly regarded as the " Father of Medicine ".

Although the people did not know the actual cause of disease they still tried to cure them by using plant and animal products. For example the Peruvians used the *Cinchona* bark for treating malarial fever. The ancient Chinese used *Ephedra* for treating asthma while the ancient Indians used Sarpagandha (*Rauvolfia*) for treating cases of high blood pressure.

(*b*) *Types of diseases*

Today our knowledge of the origin and nature of various diseases has grown substantially. We can classify diseases generally as follows:

(i) *Infectious diseases* : These are usually caused by certain micro-organisms such as bacteria, viruses, protozoa,

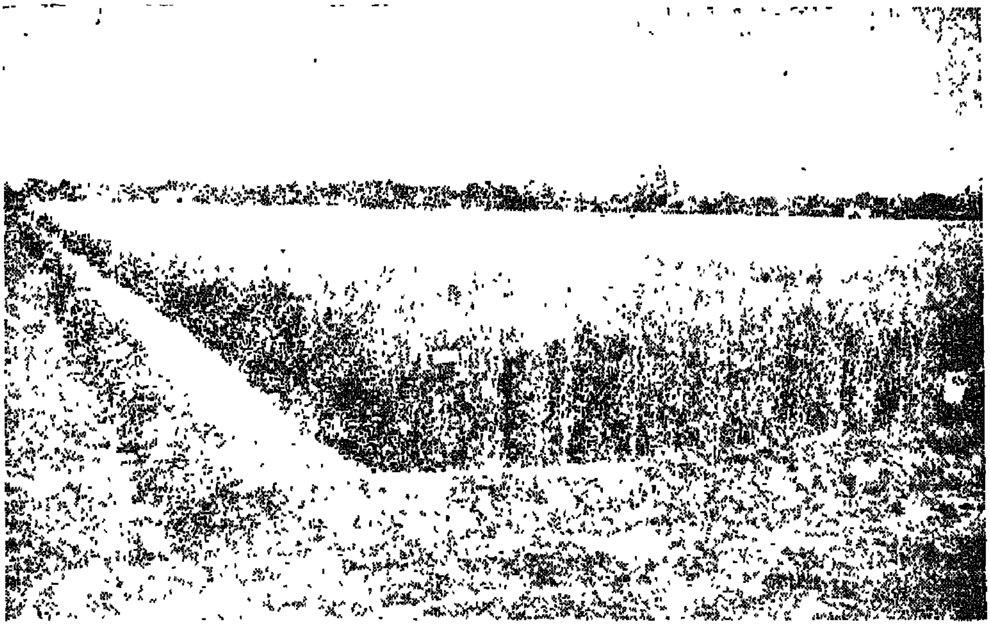


FIGURE 3.7 (B) 'Sonora 64', a new dwarf wheat variety from IARI, New Delhi

fungi, and certain other parasites which invade the body of the host. Toxic substances liberated by the parasite in the body of the host are responsible for the disease.

Some of the diseases like influenza, smallpox, the common cold and measles spread easily from person to person through contact. Infectious diseases are usually transmitted by insect bites, contact with sputum, stools, urine and clothing of diseased persons or through contaminated water, food and dust. Infection may also take place through the exposed parts of body like wounds, burns and scratches on the skin.

(ii) *Non-infectious diseases :* These are caused by lack of certain substances essential for the normal growth and function of the body. Rickets, scurvy, pellagra and beri-beri are examples of deficiency diseases caused by consuming food that lacks certain essential minerals and

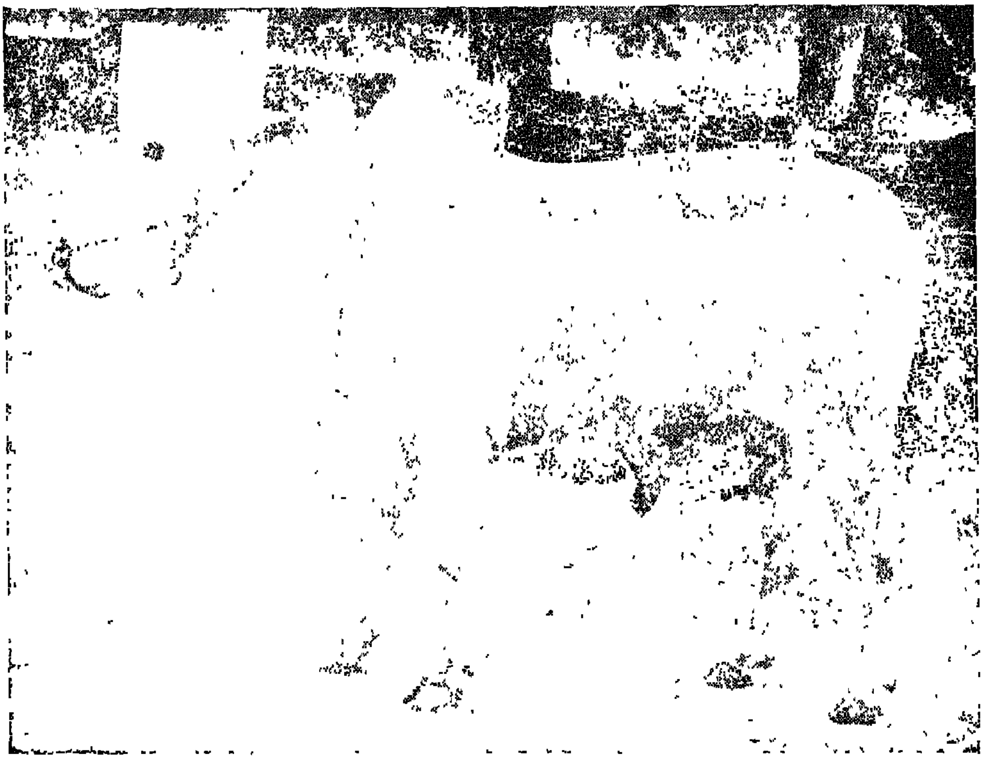


FIGURE 3.8 (A) Deoni Bull (Courtesy· Centralised Semen Collection Centre, Govt. of Andhra Pradesh, Hyderabad).

vitamins. These diseases can easily be cured by replenishing the required substance in the food or drinks.

(iii) *Allergic diseases :* These diseases occur when the body becomes very sensitive to certain foreign substances and results at times in metabolic shocks. The symptoms produced due to these are referred to as allergies. The allergies caused by certain pollen grains are good examples of this type. At times a person inhaling pollen grains of certain plants develops inflammation of the eyes and nasal membranes (catarrh). Likewise some people are allergic to certain types of proteins, oils and certain other foods. One can avoid allergies by not using such substances.

FIGURE 3.8 (B) Murrah Breed (Courtesy: Centralised Semen Collection Centre, Govt. of Andhra Pradesh, Hyderabad).

Now-a-days certain antiallergic drugs (antihistamines) are also available and if taken in time they reduce the intensity of allergies and also anaphylactic shocks.

(c) *Discovery of infectious diseases. Vaccine and serum*

Our knowledge about diseases today is largely due to the invention of the microscope and the discovery of micro-organisms or germs.

Louis Pasteur, a French chemist, put forward the germ theory of disease. He not only discovered the causes of fermentation, chicken cholera and rabies in dogs and men but also suceeded in developing a vaccine against rabies. Earlier, Edward Jenner, an English Doctor, had also used a vaccine for smallpox but it did not receive due attention as he was unable to explain its mode of action. Pasteur on the other hand scientifically demonstrated the mode of action of the vaccine he had developed against rabies.

At about the same time Robert Koch, a German bacteriologist, investigated the causes of anthrax in the animals. He not only isolated and cultured the germs that cause the disease but also experimentally proved that they are responsible for the disease.

Of late many vaccines have been developed which give protection against such diseases as rabies, poliomyelities, etc. We can combat many other diseases such as diptheria and tetanus by proper administration of the antiserum in time.

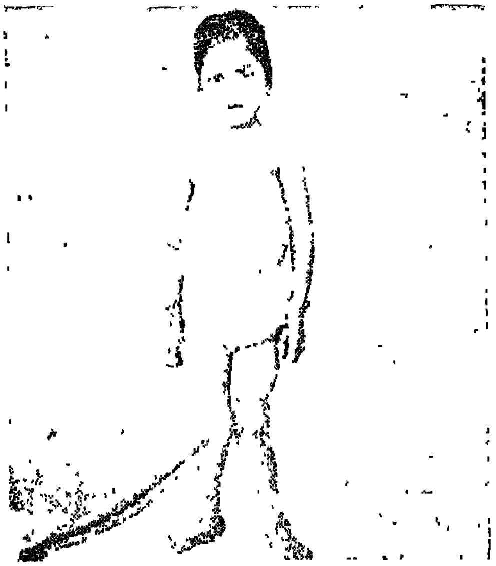


FIGURE 3.9 Child suffering from rickets (Courtesy: National Institute of Nutrition, Hyderabad, Andhra Pradesh).

Several diseases can also be controlled by knowing the methods of their transmission from one host to another.

(*d*) *Disease transmission and vectors*

Most of the diseases are transmitted by animals such as insects. Such animals are referred to as vectors. Malaria is transmitted by mosquitoes. There are several other vectors such as the

FIGURE 3.10 Robert Koch (1843-1910).

tsetse-fly, the sand-fly, the house-fly, the cockroach and the louse which transmit disease in man and other animals.

The following table may give you an idea about the diseases that are transmitted by these vectors :

TABLE 3.3

Name of the vector	*Type of disease transmitted by them*
House-fly	*Cholera, Dysentery, Tuberculosis, Diarrhoea, Typhoid.*
Mosquito	*Malaria and Filariasis*
Cockroach	*Dysentery and Diarrhoea*
Tsetse-fly	*Sleeping sickness (Trypanosomiasis).*
Sand-fly	*Leishmaniasis.*
Louse	*Relapsing fever, Typhus.*

(*e*) *Chemotherapy* (*Sulpha drugs and Antibiotics*)

In the early years of 20th century a number of drugs were developed for combating diseases. Mention may be made of the drug ' Salvarsan ' developed by a German bacteriologist, Paul Ehrlich. This yielded very good results against syphillis and yaws. Subsequent to this, in the year 1935, Gerhard Domagk, another German Scientist, discovered a red dye ' Prontosil ' which was found to be effective against certain bacterial diseases. His discovery has led to the development of a series of sulpha drugs that are now being used against many ailments.

Another important milestone in the history of medicine is the discovery of the antibiotic ' penicillin ' by Sir Alexander Fleming for which he was awarded the Nobel Prize. Penicillin is obtained from the mould *Penicillium* (*P. notatum*). During the last two decades a good number of other important antibiotics have also been discovered such as streptomycin, tetracyclines, etc. These antibiotics are useful in fighting a fairly large number of disease today and have rightly been regarded as the 'wonder drugs'.

FIGURE 3.11 (a) Gerhard Domagk (1895-1964)

These wonder drugs however have their potential dangers too. Due to their indiscriminate use the germs may develop resistance to these drugs. An overdose of these drugs can also affect the body adversely. The administration of these wonder drugs, therefore, should be restricted for specific purposes and that too when they are absolutely necessary.

(f) *Surgery*

Some diseases cannot be cured by medicine alone and at times surgery is needed to rectify some ailments and also deformities caused by accidents or injury. Surgery has a history perhaps as long as human civilization. The ancient Indians had achieved great skill in surgery. Even prior to sixth century B.C., Susruta performed and described operations that are considered not only important but also as pioneer surgical achievements. His main contributions were, however, in the field of plastic surgery. The ancient Egyptians and Chinese

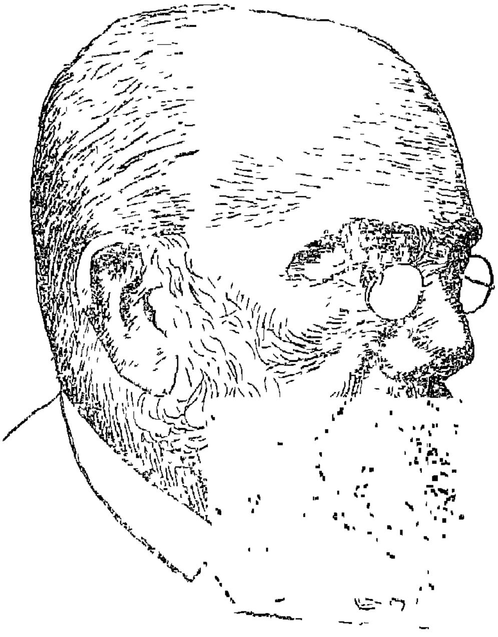


FIGURE 3.11 (b) Paul Erlich (1854-1915).

also performed surgical operations A significant advancement in surgery was achieved when Humphry Davy in 1799 discovered the use of nitrous oxide to make the body insensitive during the process of operations. Likewise the application of carbolic acid by Joseph Lister in the 19th century to avoid infection during surgery, was another important discovery in the history of this branch of science. These paved the way for anaesthesia and the aseptic methods of surgery.

The progress of surgery in recent years gives a greater hope as deaths due to the failure of any particular vital organ can be averted in cases where other vital organs of the body function normally.

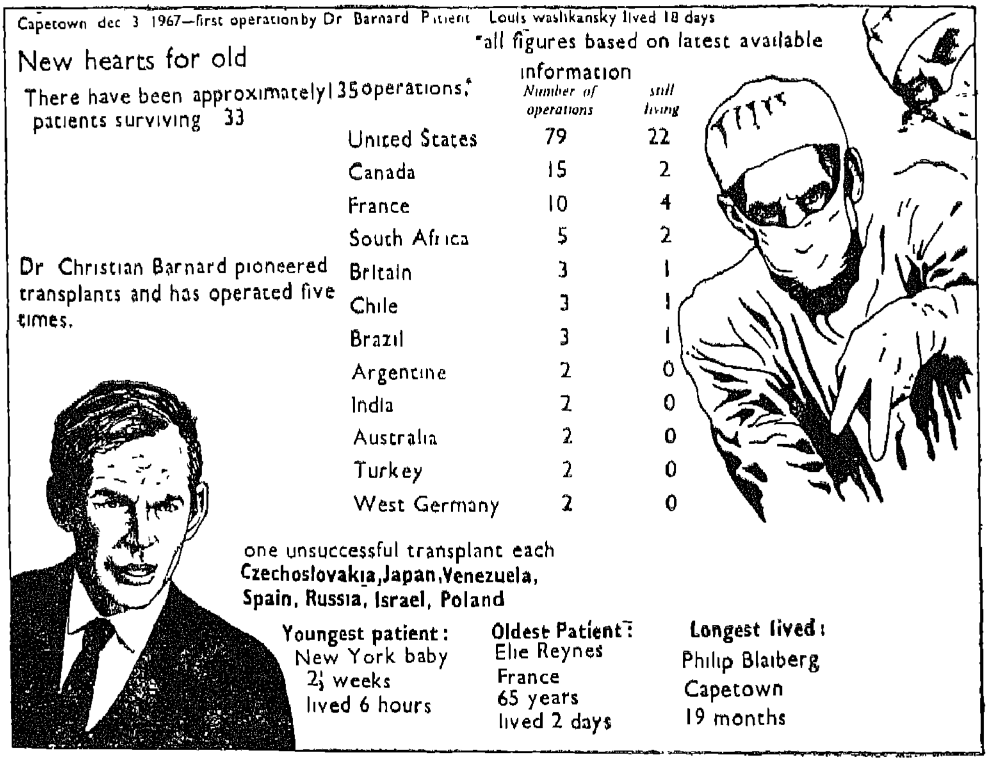
FIGURE 3.12 Lord Joseph Lister (1827-1922)

Transplantation

You must have read or heard about transplantation of human organs. Do you know what is meant by transplantation ? Transplantation involves the replacement of diseased or damaged organs by healthy ones. Transplantation method may also be referred to as ' spare parts surgery ' or ' organ replacement '. In recent years a number of organs and tissues of the body such as kidneys, heart, blood vessels and cornea have been transplanted with success.

Dr. Christine Barnard, a South African surgeon, did the first successful transplantation of the heart in 1967, and opened new frontiers in the field of surgery. It is interesting to note that his patient, Dr. Blaiberg, a middle aged dentist, lived for 19 months with a transplanted heart. The data about the progress of transplantation surgery in different parts of the world is given in Fig. 3.13.

Transplantation is very promising, and one day we may have banks for spare parts of human body just as we now have the eye and blood banks. In these banks, organs such as kidney, liver, spleen, lung and even heart can be maintained under suitable aseptic conditions for subsequent use in transplantation surgery.



Capetown dec 3 1967—first operation by Dr Barnard Patient Louis washkansky lived 18 days

New hearts for old

*all figures based on latest available information

There have been approximately 135 operations,* patients surviving 33

Dr Christian Barnard pioneered transplants and has operated five times.

	Number of operations	*still living*
United States	79	22
Canada	15	2
France	10	4
South Africa	5	2
Britain	3	1
Chile	3	1
Brazil	3	1
Argentine	2	0
India	2	0
Australia	2	0
Turkey	2	0
West Germany	2	0

one unsuccessful transplant each
Czechoslovakia, Japan, Venezuela, Spain, Russia, Israel, Poland

Youngest patient:
New York baby
2½ weeks
lived 6 hours

Oldest Patient:
Elie Reynes
France
65 years
lived 2 days

Longest lived:
Philip Blaiberg
Capetown
19 months

FIGURE 3.13 Progress in Transplantation Surgery.

In the present century, the span of life of man has steadily increased not only due to the advancement in medicine and surgery but also due to the availability of protected water supply, hygienic measures, good surroundings and other comforts in the advanced societies. It is on account of this that today man lives a longer and healthier life than his forefathers did a century ago. Today the people of developed countries are living up to a ripe old age in sound health. The question now arises what causes *old age*.

In old age man develops many disabilities. For example, the heart, the blood vessels, bones, eye sight and memory suffer most with age. The weakening of heart muscles and the hardening of blood vessels result in poor circulation of blood. Lack of proper supply of blood to the vital organs leads in their gradual degeneration resulting in the curtailment of their normal functions and finally causes death.

Does old age set in uniformly at the same rate in all the individuals ? No. A person's way of life plays an important role along with other factors in influencing the senile changes in his body. In the developed countries like Russia, America and U. K., people are economically well off and more educated. Since they take care of their health from the very beginning, the onset of senility is comparatively late in their life.

If precautions are not taken, old age may set in relatively earlier. In our country a person at 55 looks much older than his counterpart in the developed countries. This is obviously premature ageing which might be due to several reasons. For example an undernourished person who has to work hard to earn his living may age rapidly.

We do not have as yet exact knowledge of the physiological processes which lead to old age. It, however, appears that the excessive or low secretions of some of the hormones (hormonal upset), a fall in the potassium content in the body, the degeneration of individual cells and their disappearance from the tissues are perhaps the likely causes that positively influence the ageing process. Besides these, constant mental worries, nervous tension due to present day economic and social commitments affect the body adversely and these may consequently lead to premature aging.

Pests

(*a*) *Common pests and their harmful activities*

All the organisms which constantly damage or cause economic loss either directly or indirectly to human beings are considered as pests. Earlier in this chapter you have learnt that certain insects and a few other animals transmit highly infectious diseases. Man is primarily concerned about these pests because, besides transmitting the disease, some of these either feed on the human blood or cause discomfort to him. He is also equally worried about those pests which either rob him of his

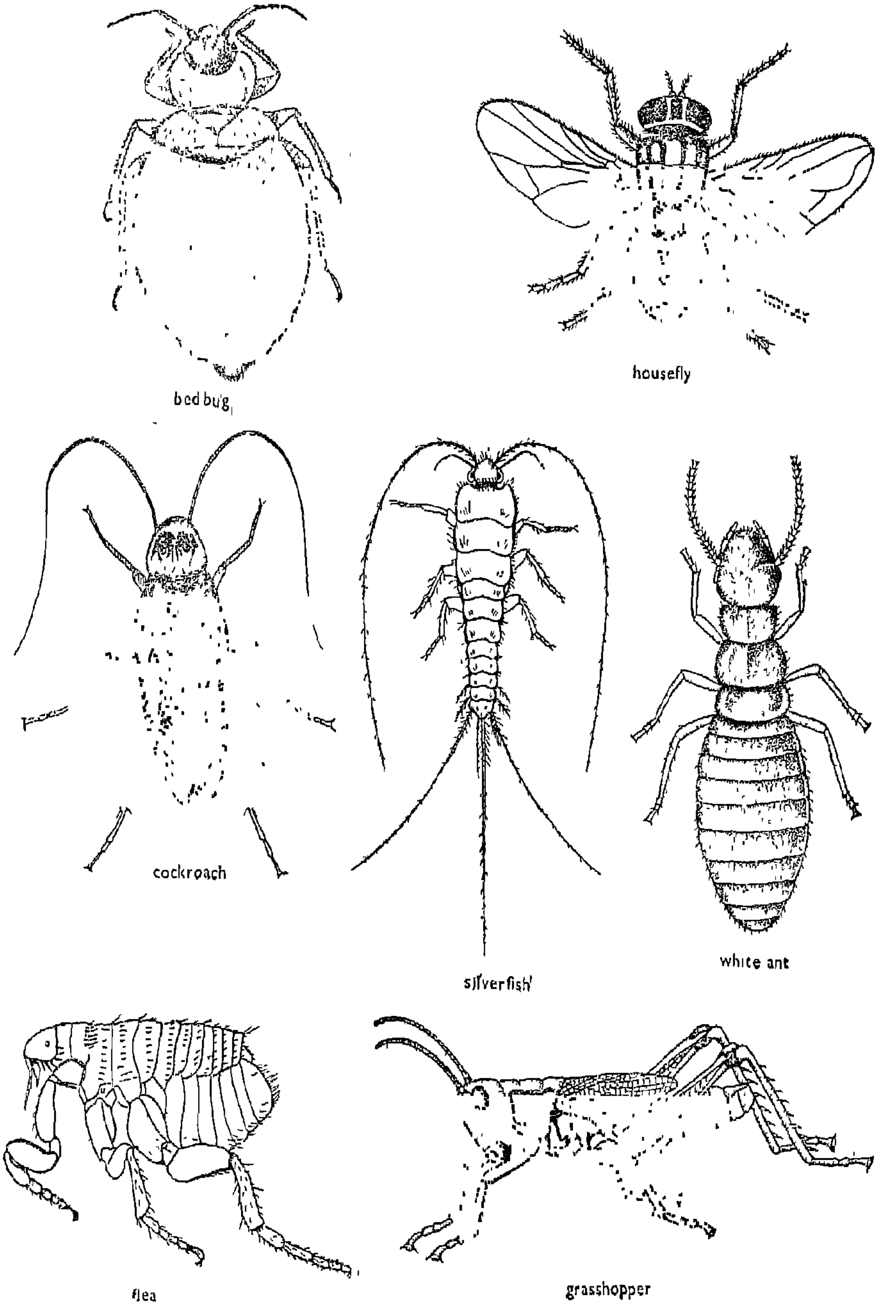


FIGURE 3.14 Some common insect pests.

food in large quantities or spread diseases amongst the useful plants and animals.

The pests pose a great problem to man as they spoil a considerable amount of his produce every year. In the following table, the monetary value of the crop damage due to pests as estimated by the Food and Agricultural Organization of the United Nations for three countries is given :

TABLE 3 4

Name of country	*Loss per year*
U. S. A.	2000 *million pounds*
India	275 ,,
Britain	140 ,,

From the table it is clear that there is a constant drain of money and labour due to these pests. It has been said that rats alone consume about 3 million tonnes of food grains annually in our country. The problem of pests however is not a recent one. In ancient Indian scriptures (Rigveda) there are hymns invoking gods to protect their fields and cattle from pests and diseases.

(*b*) *Pesticides*

One of the early methods of controlling these pests was by manually segregating and destroying them. Even today some of the pests are controlled by this method.

The extracts obtained from poisonous plants such as nicotine and pyrethrine powder are being used against some pests since a long time. Besides these plant products, a good number of arsenic compounds, flourides and oils are also frequently used to check their populations.

However man is not completely satisfied with the pesticidal properties of these different substances. In the search made by chemists for better substances, a number of them were discovered but a few of them such as DDT (Dichloro-diphenyl-trichloroethane), BHC (Benzene hexa-chloride), dieldrin, chlorodane and lindane are found efficacious.

In 1939 Muller brought to light the powerful insecticidal properties of the synthetic chemical DDT. Since then this has been used against a variety of pests with very good results. For example, deaths due to malaria are negligible now in our country mainly due to proper dusting and spraying of this chemical in places where mosquitos breed and abound.

However, the constant application of such pesticides also creates certain problems. For example, when DDT or any other pesticide is applied to crop plants, a large population of harmless insects which visit these crops are also destroyed. This deprives the birds of their insect food, which may eventually reduce the bird population. Indiscriminate use of pesticides has resulted in the upsetting of food chains and in extreme cases may even result in the eradication of some animal species from the face of the earth.

There are also indications on the other hand that insects are developing resistance to such chemicals and consequently their population is tending to increase uncontrollably. The modern investigation shows that the use of DDT is posing a growing threat to animal life on earth as it is a persistent cumulative poison. Scientists are now trying to find out certain other alternative pesticides which are less poisonous and are equally effective against pests.

The problem of pest control has to be tackled very carefully on diversified lines to minimise its evil effects. A few such measures are discussed below :

(*c*) *Biological control*

One of the alternative methods of pest destruction is biological control which is based upon the careful exploitation of many pest-predator and host-parasite relationships. A detailed study of the life history of the pests, their predators, hosts and parasites would certainly afford better clues in this direction. Although application of biological control for checking the insect pests appears to be of recent origin, actually the ancient Chinese are known to have adopted similar methods. The best example is the use of ants to check the boring insects from damaging orange plants.

The spread of some of the pests is largely due to the curiosity of men. For example, this is true of the rabbits introduced in Australia for sport. These rabbits in the absence of their natural enemies in the new environment multiplied rapidly in large numbers and became pests.

To get rid of snakes the people of Jamaica imported mongoose from our country. This mammal, no doubt minimized the population of rats and snakes, but now it is forced to feed upon eggs of birds since rats and snakes have become scarce.

(*d*) *Other control measures*

The strict isolation (quarantine) measures enforced in the different countries in recent years are of great help in checking the further spread of pests.

Dr. Edward Knipling suggested sterlization method as a means for controlling the insect pests. He first tried this method on screw worm fly which is a serious pest of the cattle. The females of this insect mate only once during its life time while the males are polygamous. Edward Knipling reared the males in large numbers and sterilized them by X-ray treatment. Subsequently, he released these sterile males in Curaco Island where this insect population was very large. After mating with sterile males, the female insects produced infertile eggs and the population gradually decreased.

Weeds

Besides the pests, a good number of plants also cause inconvenience to man. You might have experienced in your garden or farm that in addition to the plants that you grow, a good number of other useless plants occupy the space. These undesirable plants are usually termed as weeds. They cause considerable loss to man because they not only occupy the space but also compete with the crop plants in drawing the available nutrients from the soil. These weeds usually grow more rapidly than the useful plants and hinder their development. Every year, the farmer is forced to spend money to manually remove and destroy these weeds. To get over this difficulty chemists have tried to develop certain good weedicides and herbicides which have selective effects on unwanted plants. As you know they have introduced certain chemicals like 2, 4-D (2, 4—dichlorophenoxy-acetic acid) which when applied in dilute concentrations becomes toxic to plants. Even this toxicity is selective, and it sometimes destroys the broad leaved plants. This has been successfully employed against the weeds in the cereal crops.

However, the biological control method is also of great importance in checking the growth of certain weeds. For example, the prickly pear (Opuntia) which was inadvertently introduced into this country by some cactus enthusiasts, spread so widely and occupied vast tracts of fertile lands that the Government was worried about controlling it. The biologists were aware of one of its enemies, the cochneal insect which controlled its growth in Australia. Consequently the insect was introduced from Spain into our country and within a few years, it almost eradicated this weed.

Fungi

A good number of pathogenic fungi also cause considerable damage to crops. The great Irish famine in the year 1945-46 was due to heavy damage to potatoes caused by the fungus, *Phytophthora infestans*. Similarly, in India, the Bengal famine in the year 1942-43 was partly due to *Helminthosporium oryzae*, which caused enormous loss of paddy crops. Man is trying his best to avoid losses due to fungi, by spraying certain fungicides such as Bordeaux mixture, and sulphur dust, and also by breeding new crop varieties which are resistant to fungal attacks.

Population explosion

Population is one of the greatest problems that mankind faces today. During the prehistoric age when hunting and gathering of vegetable food were the only means of sustenance of life, the human population was very limited. But when man turned out to be a producer, the population registered some increase due to security and increase in food supply. However, the population increase in the entire world was relatively negligible till the middle of 19th century, but subsequently it started showing an upward trend. In the last three or four decades, it has increased enormously. The increase of population is also due to the advancement of medicine and science which has helped in reducing mortality rate resulting in an increase of the life span of individuals. For example the average life span of an Indian towards the end of the nineteenth century was 24 years, while today it is 42 years. With the increase of the life span, most of the individuals are provided with a longer potential period of reproduction. Besides the fall in the death rate, the fecundity of individuals during the increased span of their life seems to be mainly responsible for the increase in population.

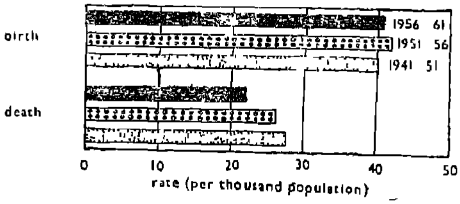


FIGURE 3.15 Chart showing the rate of birth and death in India from 1941-1961 (from Scientific American, 1963).

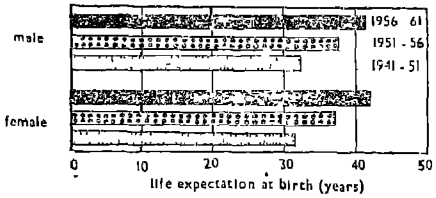


FIGURE 3.16 Chart showing life expectation at birth in India from 1941-1961 (from Scientific American, 1963).

The world population at present is nearly 3.36 billion, and it is increasing roughly at the rate of 1,40,000 per day. At the present rate the population is likely to double within less than every thirty-five years.

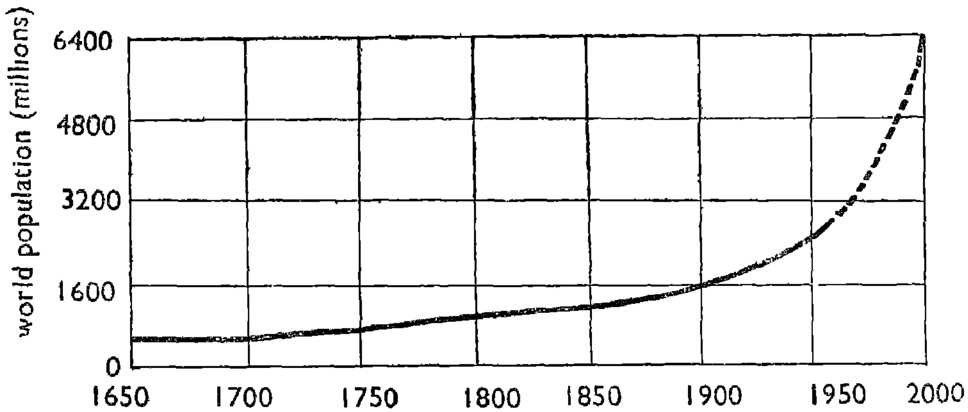


FIGURE 3.17 Chart showing the population of world from 1950-1960 projected to the year 2,000 (from Scientific American, 1963).

Towards the end of this century the population might reach 6 billion mark.

Population increase would not have been such a major problem if there had been a corresponding increase in food production. Unfortunately, this is not the case in certain countries of the world. Besides, the population is not equally distributed in different parts of the world. From the map, you can see that the high densities of population are found in our country and in China.

The population of our country is 530 millions, i. e., nearly 1/6th of the total population of the world. Approximately 21 million babies are born every year in our country while about 8 million people die resulting in a net addition of 13 million individuals every year. There is little scope for increasing the food production by getting more and more land under cultivation to meet the demands of the fast growing population. As it is, most of the people in our country are undernourished and the caloric value of average Indian diet is very low.

Though the food production has been stepped up to a considerable extent in recent years in our country by following improved agricultural methods, it has however not altered the per capita consumption significantly. It appears that as long as the present birth rate continues, any amount of increased production in the field of agriculture and industry

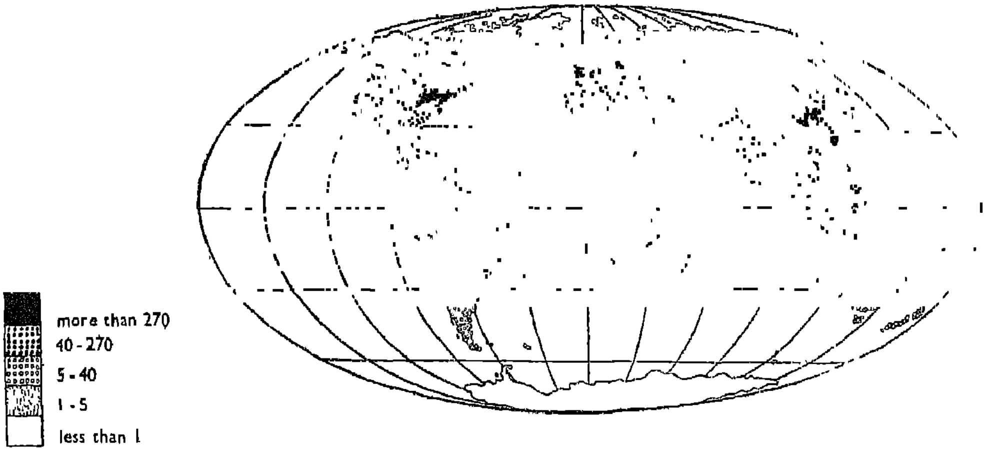


FIGURE 3.18 Map showing population density as in 1961. The densities are given in terms of the number per square kilometer (from Scientific American, 1963).

will not improve the economic condition in our country. As it is, the gross imbalance between the population and the food resources has brought competition for food and living space in mankind. We know the worst competition for existence would be amongst the members of the same species (intraspecific competition) as all of them depend on the same kind of food and other resources. The intraspecies competition awakens the instinct of self-preservation.

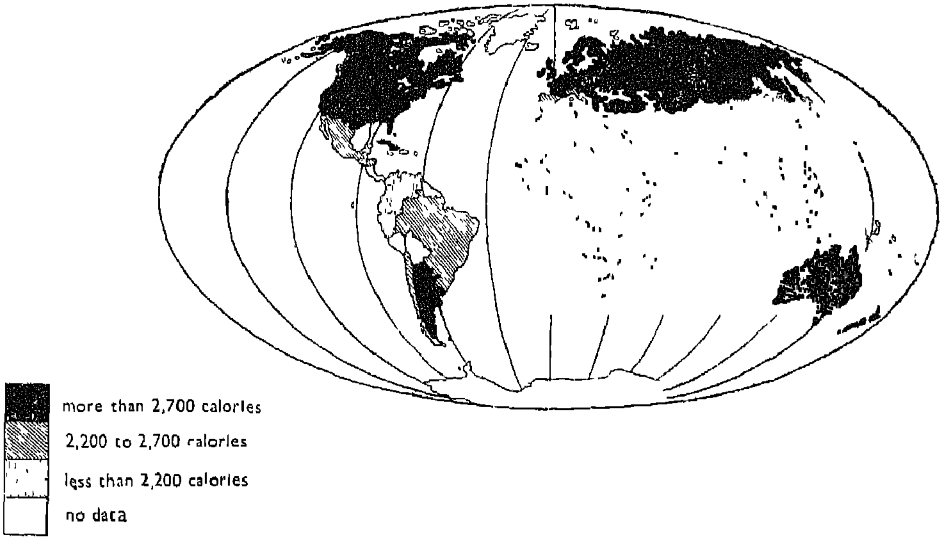


FIGURE 3.19 Map showing caloric values of diet. Number of calories per person per day as estimated by F.A.O. in 1962 (from Scientific American, 1963).

In general competition is reflected in racial, provincial and regional feelings amongst men merely for their own existence and well being. It has brought in discrimination against men on the ground of colour, country or religion. In fact racial hatred has been fanned by ill-informed people who are afraid about their security.

The instinct of self-preservation is not restricted to man alone. Perhaps man has inherited it from his animal ancestors and therefore it is an animal instinct. Everybody knows how a small school of monkeys jealously guard their feeding grounds and if one or another family of monkeys trespass, a fight starts, sometimes leading to deaths on both the sides. The biologist calls this ' territorial fights ' because the animals are trying to guard their feeding grounds and are afraid of encroachment by others. This instinct is also found in dogs, wolves and hyaenas. As a matter of fact, the territorial fights are found even today in the less civilized nomadic tribes. But as man becomes civilized he develops a better attitude towards life and towards his fellow citizens.

Nationalistic feelings are nothing but territorial feelings. Provincial and racial feelings are the worst because they act in still narrower fields. The great wars and tragedies of the past were also due to a sense of insecurity that prompted the animal instinct to aggressive nation.

One great contribution of the Biological science to the society is that it has proved beyond doubt that human species is one and that discrimination on the basis of the country of their origin, colour or creed is unscientific. It has been shown that the population could be controlled by following scientific methods and not by wars.

The scientific devices followed usually to decrease the birth rate are :

(i) Postponement of marriages
(ii) Use of contraceptive
(iii) Raising frequency of sterilization
(iv) Abortion

Japanese people have adopted all these methods to control the population explosion. Only five per cent of the Japanese girls are known to marry below the age of 20 years. It is a matter of interest to know that in Japan the birth rate per thousand dropped from 34.3 in 1934 to 20.1 in 1947. On the other hand in our country the girls marry at a very early age. We should also find an effective method to discourage these early marriages.

In view of the gravity of the population problem the State Governments and the Government of India have given top priority for family planning.

Pollution

Earlier in the chapter "Conservation" you had learnt some details about pollution of water. You know how the pollution problem is closely linked up with the mode of disposal of waste materials.

The early men possibly had not faced this problem because, as the population was then limited, the waste materials were very slight and the natural agents rapidly decomposed those substances. With the increase in the density of population there is an increase in the amount of refuse and their quick disposal has become a problem. Usually the waste materials are channelled into the flowing waters and the sea.

A little addition of sewage to an aquatic body is possibly to some extent helpful to certain living organisms as it acts as a fertilizer due to immediate decomposition.

Aquatic bodies can purify nearly one-fiftieth of its own volume of sewage. If a greater amount of sewage is directed to these bodies, then the natural agents will not be able to decompose these substances completely. As you know in such circumstances the oxygen content of the water usually gets depleted and anaerobic conditions set in. These waters would be highly turbid and they are unfit for consumption. They support very little aquatic life.

Large scale pollution started with rapid industrialization and the release of waste materials of the industries into the environment. Air pollution is largely due to the release of chemical wastes of the industries into the environment.

In addition to these a considerable amount of poisons such as pesticides, fungicides and weedicides that are employed for different purposes would ultimately find their way into the waters.

There seems to be a direct relation between pollution and human disease. Polluted air and water are largely responsible for the incidence of diseases like asthma, bronchitis, pneumonia, tuberculosis, cholera and dysentery.

The pollution of environment is the result of human activity. Pollution is thus an essentially biological problem which needs immediate attention. However, after realizing the grave danger, pollution has been prohibited by law in most of the countries and a large number of sewage treatment plants have been established to purify the sewage before it is actually released into the environment. This has however not solved the problem completely and even today the pollution is posing a great threat and the problem is more severe in the cities. Precautionary measures are, however, taken and the establishment of the industries in the immediate vicinity of the cities is discouraged.

As pointed out earlier in the chapter 'Conservation' efforts should be made to avoid pollution of the environment by all the individuals failing which large scale epidemics would occur in human societies over and again.

It was stated earlier that man was at the mercy of his environment till 10,000 years ago, but today we can say that environment is at the mercy of man. If we do not do something to bring about a balance between the two and if we do not take measures to prevent pollution and conserve our natural resources, man would probably be destroying his own species.

Eugenics

You have learnt earlier that the knowledge of heredity has helped to improve the stock of animals and plants. The application of the same principles for the improvement of the human race is attracting considerable attention from the geneticists. This branch of science is called eugenics.

The approach to eugenics is by encouraging the breeding of those presumed to have desirable genes and discouraging the breeding of those considered to have undesirable genes. For example, there are a large number of human beings in the world who suffer from serious diseases which are known to be hereditary (mental defects). Such people should be advised properly not to have children as the children are also more likely to have these defects.

By following this procedure, we can check the hereditary diseases in the human society.

Space exploration

You have studied so far in this Chapter how man from a relatively helpless position, leading a nomadic way of life, gradually solved the problems that concerned him most, and achieved considerable success.

Man by nature feels little satisfied with his achievements. He would always find new problems and attempts to find the solutions. This curiosity of man is the key note of his success.

Being an articulate and thinking organism he has an advantage over other animals in transmitting the knowledge gained by experiments to his race in spoken and written language. The greatest accomplishment of man in the present century is the conquest of space. In this adventure man was successful in landing on the surface of the moon. He has even collected samples of moon's surface material.

At present man is able to spend very little time away from earth's territory because he has adjusted himself to life on earth and necessities of life available here. Man is trying his best to find alternate possibilities and if he is successful in these ventures he could think of prolonged journeys to other planets.

Earlier we have studied the position of man in the food chain. In the outer space man should arrange for his requirements of life. At present he is carrying his food and even the supply of oxygen in his space trips. The biologists are engaged in discovering a closed food chain which might solve this problem. The answer possibly lies in certain photosynthetic micro-organisms.

Man's accomplishments in the field of science and technology are miraculous. There are possibilities of further achievements with the greater co-operation amongst the individuals irrespective of their creed and nationality. Once this is achieved it will no doubt be the dawn of a new era in the history of mankind.

GLOSSARY

Aborigines—The original or native inhabitants of a country.

Allergy— A tendency to react unfavourably to the presence of a certain protein compound or any other agent.

Anaesthetic—Substance used in medicine to produce insensitivity or loss of sensation.

Analogy—Resemblance of external feature or function between organs of different structural features or origin.

Anthrax—A contagious disease of cattle.

Antiallergic—Preventing or lessening allergy.

Antibiotic—Substance produced by living organism which diffuses into its surroundings and is toxic to individuals belonging to other species. *eg*. 'penicillin' produced by *Pencillium* species.

Antihistamines—Drugs which suppress some of the effects of released histamines.

Antimalarial—Any measure taken to prevent or suppress malaria.

Antiseptic—Substance that kills pathogenic microbes but is too toxic to be used except on the outer surface of the body.

Antitoxic sera—The serum of horses which have been immunised by injections of pathogenic bacterial toxins such as tetanus. Such serum contains antibodies or antitoxins and after injection confers temporary immunity against the original toxin.

Beri beri—A deficiency disease caused by lack of vitamin B_1 (*Thiamin*).

Contagion—Communication of disease from body to body.

Diphtheria—An acute, specific disease caused by a bacterium (*Corynebacterium diphtheriae*).

Disinfectant—A substance which will destroy disease producing microorganisms. It is usually applied to substances for external application only.

Epidemic—Condition which exists when many people in the community contact a disease at about the same time.

Eugenics—The branch of science which aims to improve the human race through controlled breeding.

Fermentation—Decomposition of organic substances by organisms (such as bacteria and yeasts). The conversion process of sugar into ethyl alcohol and carbon dioxide by yeast.

Fossils—Remains of organism of prehistoric ages found preserved in strata of earth or rocks by natural causes with more or less chemical and other texture changes.

Fungicide—An agent which is lethal to fungi.

Gene—Unit of heredity; a particular segment of a DNA molecule, generally located in the chromosome.

Genotype—The particular and relatively constant genetic material of an organism.

Germ—Any microscopic organism such as bacteria, protozoan, or virus that causes disease (pathogenic microorganism).

Herbicide—A chemical weed killer such as 2, 4-D.

Homology—Structural similarity of an organ or part of it in one type of animal with the comparable part in another due to descent from a common ancestor.

Hybrid—Plant or animal resulting from a cross between parents that are genetically different in one or more characters.

Infection—Successful invasion and establishment by disease causing organisms in the tissues of a host plant or animal.

Instinct—A form of behaviour usually referring to a series of inborn or unlearned reflexes.

Malaria—A tropical disease caused by a protozoan (*Plasmodium*), carried and injected by mosquitoes of the genus *Anopheles*.

Mutation—An unexpected trait in an offspring which differs from its parents. Sudden relatively permanent chromosomal change.

Nicotine—A poisonous substance found in tobacco plants.

Nomads—Those dependent principally on hunting or collecting for their food supplies, having no permanent abodes

Ontogeny—The developmental history of an individual organism.

Package programme—An intensive agricultural district programme launched by Government of India in co-operation with the Ford Foundation The farms covered by this programme would receive supplies of improved seeds, fertilizers and insecticides.

Pellagra—A deficiency disease caused by lack of vitamin B complex and protein.

Pesticide—A material used to control pests.

Phenotype—All the different biological appearances including structural, behavioural characteristics, that are externally visible about an organism.

Phylogeny—The evolutionary history of a species or higher groups of organisms

Poliomyelitis—An epidemic virus infection causing paralysis usually in children.

Polyploidy—State of having more than diploid set of chromosomes.

Prophylaxis—Prevention.

Quinine—A drug used in the prevention and treatment of malaria. Obtained from the plant *Cinchona.*

Rickets—A disorder of calcium and phosphorus metabolism caused by a deficiency of vitamin D_1 and beginning often in infancy and early childhood between the ages 6 and 24 months.

Scurvy—A deficiency disease caused by lack of vitamin C (ascorbic acid).

Selective Breeding—Induced mating between selected stocks to yield desired progeny.

Serum—The fluid remaining after removal of fibrinogen from blood plasma.

Tetanus—Disease caused by a bacterium (*Clostridium tetani*).

Toxin—Waste product given off by a bacterium which is poisonous.

Vaccine—Suspension of weakened or dead pathogenic organisms which when introduced into the body stimulates the production of antibodies.

Variation—(structural) differences in appearance among the individuals of the same species of plants or animals.

Vector—Carrier organism that aids in the dissemination of a disease organism.

Weed—Any useless plant which grows without intentional cultivation.

DEAR READER,

In presenting another set of Biology Text Books IV to VI and Teacher's Guides at an advanced level over Books I—III, already published, we have set to address students of the Indian Secondary and High Schools. The same Biology Study Groups that edited the previous set are now presenting this series for try outs on as wide a scale as possible.

Whilst it is true that the teaching of biological sciences in the West has made great strides since 1960, we have not as yet geared ourselves to the task of bringing the materials within the comprehension of the young Indian students. The reasons are many and among them two seem most important. The teacher has few authentic texts designed for our Indian conditions and the school laboratories lack some of the basic equipment necessary for meaningful demonstrations which are so vital for understanding biological phenomena. The bringing out of a text, therefore, seemed the most urgent task and once this was made available, thought could be bestowed on developing kits, charts and audiovisual aids that could make the teacher's task simpler and more direct than now. For the first time in our country, a large section of biologists in the Universities have collaborated in this programme of science education in schools and these books are the result of their efforts.

We have genuine pleasure in sending these volumes to you with the definite purpose of eliciting your suggestions for improvement of this experimental edition. We enclose a questionnaire which kindly fill after studying the books and return to us.

Biology Text Books and Teacher's Guides (I—III) are currently under revision taking into account the valuable comments received from many teachers and educationists who very kindly offered their suggestions for improvement. It is expected that these revised books will be in the field when we have had more time to finalize the text matter

Yours sincerely,

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